Journal

of

The Franklin Institute

DEVOTED TO

SCIENCE AND THE MECHANIC ARTS

VOL. 193.—Nos. 1153–1158
(97th YEAR)

JANUARY-JUNE, 1922

THE DELAWARE RIVER BRIDGE BETWEEN PHILADELPHIA AND CAMDEN.*

BY

RALPH MODJESKI, D.ENG.

Chief Engineer, Delaware River Bridge Joint Commission, Philadelphia, Pa.
Member of the Institute.

THE Delaware River Bridge will of necessity be a long span structure. It must present no obstacles to navigation within the harbor of Philadelphia. The War Department would not sanction any bridge within the port limits which would require piers to be placed between harbor lines, and justly so, for any obstruction between those lines would be very objectionable and might seriously interfere with the future development of the harbor.

When the Board of Engineers appointed by the Delaware River Bridge Joint Commission on September 24, 1920, began its studies, it at once became apparent that a span of not less than 1750 feet between centres of supports would be required, irrespective of its location. The location was limited by the city limits of the two cities which the bridge is to connect. A further limitation was placed by the Act of Congress of February 15, 1921, fixing the limits at Green Street, Philadelphia, on the north, and South Street on the south, to points approximately opposite in Camden.

---

* Presented at the stated meeting of the Institute held Wednesday, October 19, 1921.

In a paper presented before this Institute in 1913, I stated that suitable types of spans for various span lengths are: .

For spans up to 750 feet............. Simple spans
For spans from   650 feet to 2000 feet. Cantilever spans
                                                              with suspended
                                                              span
For spans from 1500 feet to 4000 feet. Cable suspension
                                                              spans

I pointed out that the above limits overlap and that local conditions should be considered in deciding whether a span between 650 and 750 feet should be a simple span or a cantilever, or whether a span between 1500 feet and 2000 feet should be a cantilever or a suspension span.   And I referred to certain objections, under certain conditions, to the suspension type.   In a railroad bridge, unless it is to carry a large number of tracks, the span may be loaded to its full capacity on one part of the continuous structure, while at the same time there may not be any load on the other.   Such conditions produce in a suspension span large wavelike deflections which are objectionable and tend to cause undue wear in the many connections.   But in a highway bridge, the loads are always fairly well distributed over its entire length, and a condition of such unequal loading as may occur in a railway bridge can only be produced artificially.   The greater the capacity of the highway bridge, or, in other words, the more lines of travel provided for, the more evenly will the simultaneous loading be distributed.   The Delaware River Bridge is a highway bridge.   It will have six lines of vehicular traffic and four lines of rail traffic for street car and rapid transit purposes.   All together, not counting the sidewalks, ten lines of travel.

The distance between Philadelphia and Camden harbor lines varies from about 1690 feet at Callowhill Street, Philadelphia, to 1763 feet at South Street, Philadelphia, or a total variation of about 73 feet.   Since the length of span would be between 1500 feet and 2000 feet the type of span, whether cantilever or suspension, could not be determined without a thorough investigation of both types. A span of 1750 feet was assumed for this investigation.   The loading was assumed to be as follows:

Two lines rapid transit tracks, each at 2000
    lbs. per lin. ft. . . . .   4,000 lbs.
Two lines surface cars, each at 1500 lbs.
    per lin. ft. . . . .   3,000 lbs.
57 ft. roadway at 70 lbs. per sq. ft. . . . .   3,990 lbs.
20 ft. walkway at 50 lbs. per sq. ft. . . . .   1,000 lbs.

Total per lin. ft. . . . .   11,990 lbs.

Twelve thousand lbs. per lineal foot of bridge is therefore taken as live load. This loading will be referred to later. Given the span length and the loading, two designs were prepared, in sufficient detail for a close estimate—one a suspension bridge, with wire cables, and the other a cantilever bridge with a suspended span. Everything else being equal, the cost of the cantilever type was shown to be nearly $2,000,000, or about 13 per cent. more than the suspension type. In this comparison, the cost of the main structure only has been considered. This great difference in cost would no doubt have been sufficient to throw the balance in favor of the suspension design, but there were other considerations, such as the more graceful lines, the greater safety during construction, and the fact that it lends itself to a greater subdivision of contracts. And all these were additional factors in leading the Board of Engineers to recommend the suspension type.

This subdivision of contracts means that in the suspension design, contracts may be let in sequence as follows:

First—the main piers,
Second—the anchorages,
Third—the steel towers,
Fourth—the cables and suspenders,
Fifth—the stiffening trusses and floor.

In the cantilever design, the superstructure would have to be let in one contract of nearly $10,000,000. This, with the funds thus far appropriated, would be impossible, and the superstructure contract would have to wait for the next meeting of the Pennsylvania Legislature, two years or more hence, before it could be awarded. The delay which such waiting would involve is evident.

The design adopted contemplates steel towers placed on granite piers which will be founded on rock by pneumatic process. The

caissons will be 70 feet by 143 feet in their horizontal dimensions and 40 feet high. They will be filled with concrete and surmounted by crib work, also filled with solid concrete. The granite facing will extend 2 feet 6 inches below low water. The borings thus far completed show the rock to be about 62 feet on the Philadelphia side and 86 feet on the Camden side below mean high water. (Fig. 1.)

We have all admired the massive masonry towers of the Brooklyn Bridge. There have also been other suspension bridges built with masonry towers. Such construction requires that the saddles on top of the towers which carry the cables be placed on rollers to accommodate the motion of the cable due to changes in loading and temperature.

Reliance then must be placed on the rollers to move freely, or the masonry tower will bend. In the Brooklyn Bridge rollers have been provided under the cable saddles. Prior to 1907 intermittent and jerky displacements of the saddles had been observed. These had the tendency to disturb the interadjustment of the cables, stays and suspenders. Rigid traffic regulations were introduced in 1907 requiring certain spacing of all trains. Since then no motion of the saddles on rollers has been observed. But motion exists, and since the saddles do not move the towers bend. While a small range of bending in masonry towers is not harmful it is not desirable because it introduces an unknown element, namely, the elasticity and resistance to bending of masonry.

In the Williamsburg Bridge the masonry towers have been replaced by steel towers which, however, were made rigid. Here also the motion of saddles was intended to take place by means of rollers. These move at times, but the frictional resistance is great and is a disturbing element.

While no one wishes to deny that at the time the Brooklyn Bridge was built, it was a masterpiece of engineering, yet since then the engineering science has not stood still. It has been recognized in the design of the Manhattan Bridge that rollers on top of the towers should be eliminated, or, in other words, the cable should be fixed to the tower tops. This can only be accomplished by making the tower flexible or by providing it with a hinge at the bottom. Since it is perfectly feasible to ascertain the amplitude or range of the motion required at the top of the tower, and since the resulting stresses in a steel flexible tower fixed at the bottom are

FIG. 1.
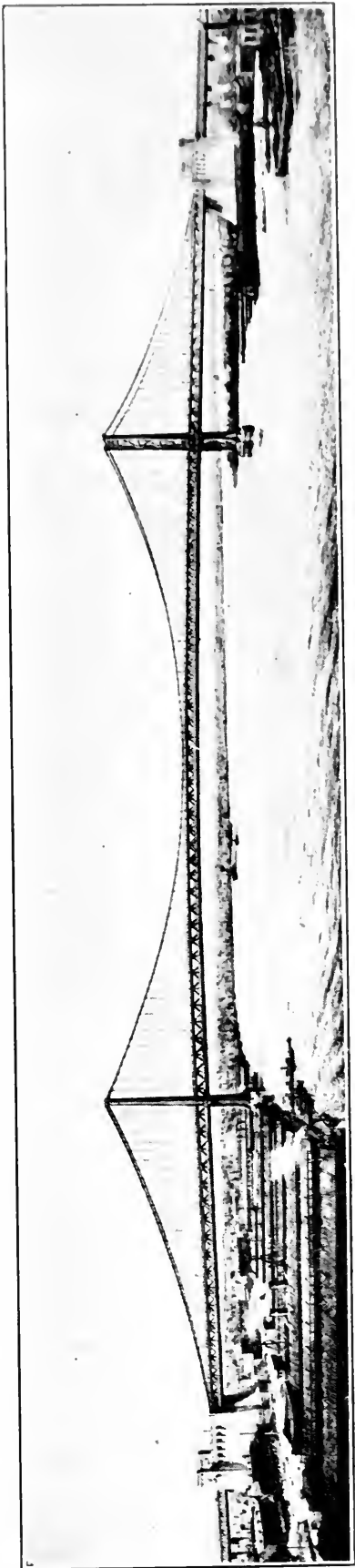
General View.

easily analyzed, such a tower has been given preference to one with a bottom hinge, as eliminating a complication in the details as well as the wear which would necessarily occur on a hinge, were it to act as such.

The elastic tower, then, provides a solution which obviates the uncertain action of the rollers on top and of a hinge at the bottom. To be elastic, the towers must be slender, so that they form a marked contrast to the massive towers of masonry of the Brooklyn or the Buda-Pesth Bridges. The slenderness of the towers of the Delaware River Bridge has received criticism from some sources and also favorable comment from others. We all know that our æsthetic sense is a matter of education. We have been educated on the Brooklyn Bridge. But a logical construction must of necessity be harmonious, and a departure from traditions is not always in the wrong direction. It is quite possible that when we become accustomed to the more graceful lines of flexible steel towers, which are certainly more in harmony with the slimness of the cables, we shall look upon the old-fashioned masonry towers as monuments, true, but rather as pioneering in the art of building suspension bridges. The total bending at the top of the towers as now designed for the Delaware River Bridge will be $21\frac{1}{4}$ inches toward the main span and $15\frac{1}{2}$ inches toward the shore under extreme conditions of loading and temperature. (Fig. 2.)

The anchorages of a suspension bridge are probably more difficult to design than any other part of the structure. This is due to the fact that they must remain immovable under the uplifting and horizontal sliding efforts to which they are subjected. The character of the soil and the depth at which solid rock is found are the main factors in determining the design of the foundations to support these large blocks of masonry in which the cables take hold. At the time of writing this paper, the borings have been completed only partly, and the design of the foundations is therefore as yet unfinished. (Fig. 3.)

We now come to the backbone of the structure—the cables. Each of the three New York suspension bridges has been built with four cables. The Delaware River Bridge will have two only, but of rather unusual dimensions. Each cable will be built of 16,500 number six wires, and will be 30 inches in diameter. It is also intended to prepare a complete design of a stiffened eye-bar type. In this connection it may be of interest to note that while a wire hanging

FIG. 2.

Tower and Main Pier.

free with the same ratio of sag to span length as the Delaware River Bridge would have to have a span length of 32,000 feet before it would reach its elastic limit of 140,000 pounds per square inch, the elastic limit of say 85,000 pounds per square inch of an eye-bar chain would be reached with a span length of only 15,000 feet. These figures are for the wire and eye-bar chain hanging free supporting their own weight only. They show that the economic advantage of wire cables increases with the length of span.

Fig. 3.
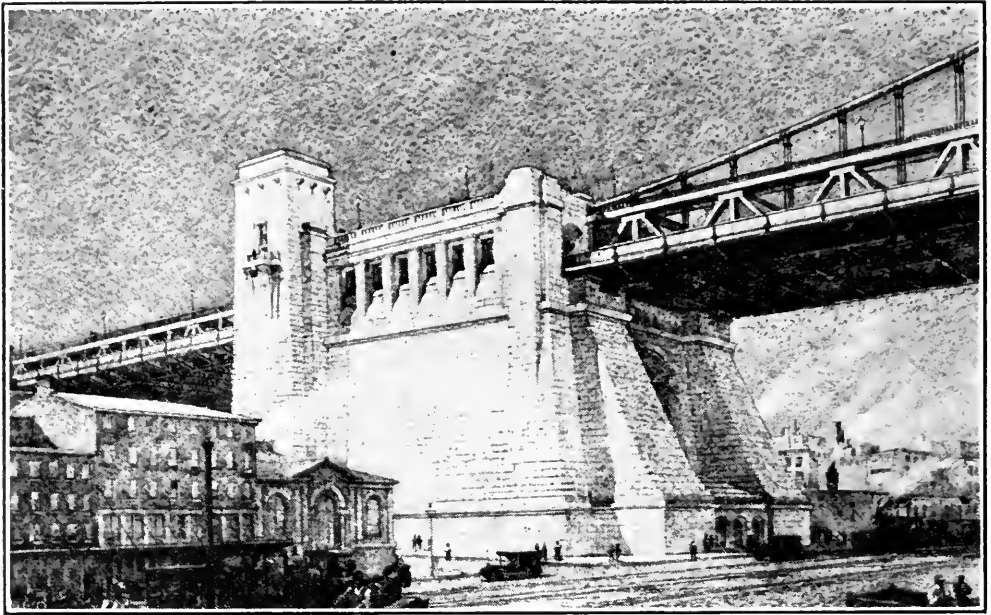
Anchorage pier.

The chief purpose of reducing the number of cables to two is to eliminate as far as possible the uncertainty of distribution of live load. With four cables, the floor beams may either be continuous, as in the Manhattan Bridge (in which case they must be strong enough to take up the unequal loading of the four stiffening trusses), or they must be hinged at the two middle stiffening trusses. In the first instance, they act as transverse stiffening girders, complicating the distribution of loading, and adding more assumptions, thus spreading the limits within which the calculations of stresses may be accepted as exact. The use of two cables only, instead of four or more, admits of a greater simplicity of design of details, as well as of the structure as a whole. It seems to be the

more direct and logical solution. In my opinion simplicity and directness should be the underlying principles of all engineering structures. This does not mean that these structures should not be made beautiful in their proportions and lines, or that some consideration should not be given to ornamentation, as long as such ornamentation is also logical and in harmony with the logical

FIG. 4.
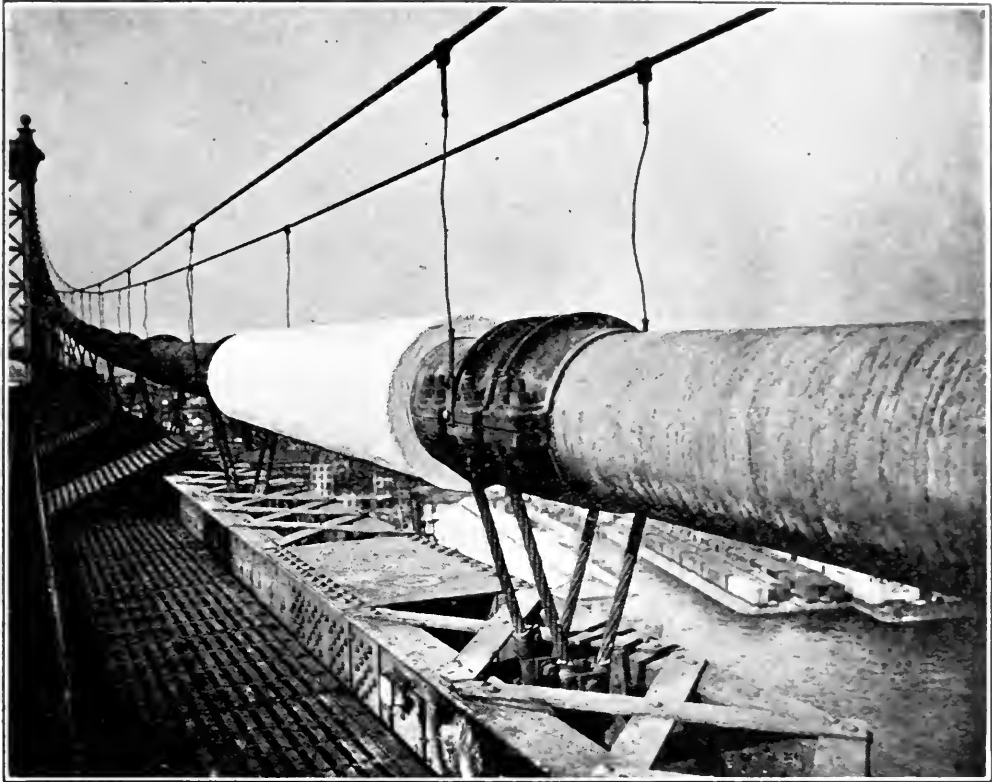
Comparative sizes of the Manhattan and Delaware River Bridge cables.

engineering structure. Neither does this mean that four, six or more cables should not be used in cases where conditions require it.

Thirty-inch cables have not yet been built. The Brooklyn Bridge cables are 15¾ inches in diameter, those of the Williamsburg Bridge, 18¾ inches and those of the Manhattan Bridge 20½ inches in diameter. There is therefore a marked increase in the size of cables of the Delaware River Bridge over those of the New York bridges. (Fig. 4.) This increase may appear somewhat bold but a close analysis of the matter shows that it only means an increase in scale without presenting any unusual difficulties of con-

struction or uncertainties of efficiency. Three main questions present themselves with a cable of this great size.

(1) The cable deflects or sags under load and temperature, causing a certain amount of bending over the tower and anchorage saddles. This results in secondary stresses. Are these stresses not excessive?

(2) What will be the efficiency of the cable as a whole, comparing it with the strength of individual wires?

(3) How will corrosion of the interior wires be prevented?

Answering these questions in their order, we find that:

(1) If the cable be considered as a solid bar of steel, 30 inches in diameter, careful calculations show that under the condition of the entire bridge loaded to its utmost capacity and the most unfavorable temperature the co-existing stresses will reach a total maximum of 79,800 pounds per square inch. Our working stress for congested loading has been taken at 72,500 pounds per square inch, or less than one-half of the elastic limit. An excess of 7300 pounds, or about 10 per cent., is permissible under conditions which are not liable to happen once in many years. But the cable is not a solid steel bar; but is made up of a multiple of wires. That stress will therefore be considerably less, and will only occur in the top and bottom wires, diminishing toward the centre of the cable where it becomes zero. Besides, it is easily provided for by an addition of material if found necessary. Then, again, the loading necessary to produce the above result will never occur. It can only be applied artificially, since it would require absolutely no load on certain portions of roadways, tracks and sidewalks, and the most congested load on others.

(2) A single wire hung from the towers with a sag of 200 feet in the centre of a 1750 foot span will be subjected to a tension due to its own weight of 210 pounds, or 7000 pounds per square inch. A variation of 1.1 inches in sag will increase or decrease this stress by 1000 pounds per square inch. By the use of carefully adjusted guide wires, strung to the exact sag required at a given temperature, all wires are set to exactly the same sag and therefore are subjected to the same initial tension. This tension is sufficient to keep them taut without kinks of any kind. The longer the span, the greater the initial tension in these wires. This initial tension is not disturbed by tying all the wires into strands or by wrapping the strands with wire into one cable. So that after

the cable is completed and hanging free, every wire is stressed to the same amount. We now hang from it the stiffening trusses, floor, etc., and send live load over the bridge—all of which produces an elongation in the cable as a whole, and it is obvious that each wire must elongate by the corresponding amount. As we all know, the stress for a given elongation is proportional to the modulus of elasticity. A series of experiments has shown that the moduli vary from 26,500,000 to 27,800,000, a variation of about 5 per cent. The stresses in the individual wires therefore cannot vary among them more than 5 per cent. This means that if the cable is stressed as a whole to 70,000 pounds per square inch, some wires may be stressed to 68,250 pounds and some to 71,750 pounds, but no wire would be stressed above 73,500 pounds per square inch.

The only factor which may tend to reduce the efficiency of the cable is the transverse pressure which the wires receive at the saddles and at the suspension points, where a transverse compression is exerted by the special castings which carry the suspender rods or cables. It is proposed to make special tests to determine how much, if at all, the strength of wires is affected by such a transverse pressure. We can only draw an inference from the action of ordinary steel cables or ropes working on sheaves, that the effect will not be material.

(3) The Brooklyn Bridge cables have been in service for 47 years. The wires of the cables were galvanized. Inspection made by the Plant and Structure Department of New York, by prying the cables open with wedges, shows that there has been no deterioration of the wires by rust or otherwise. There is no reason why these cables should not last indefinitely. The wires of the Delaware River Bridge will also be galvanized.

The loss in tensile strength of the wire due to the galvanizing is about 7 per cent.

From the cables are suspended the stiffening trusses. Their necessity has been recognized in the construction of the early suspension bridges. They serve the purpose which their name implies, that is to reduce the wave motion of the main cables under unequally distributed loads. They may be provided with hinges at the centre of the main span or with slip joints at one or more points which permit longitudinal motion, but may transmit bending, or they may be continuous over the entire main span, with pro-

vision for expansion at the towers. In the Delaware River Bridge the stiffening truss is made continuous for each span, and expansion is provided for at the towers. This has the advantage of allowing the stiffening trusses to expand in the direction of the increasing length of suspenders. The greater the motion due to the expansion the greater the length of the suspenders.
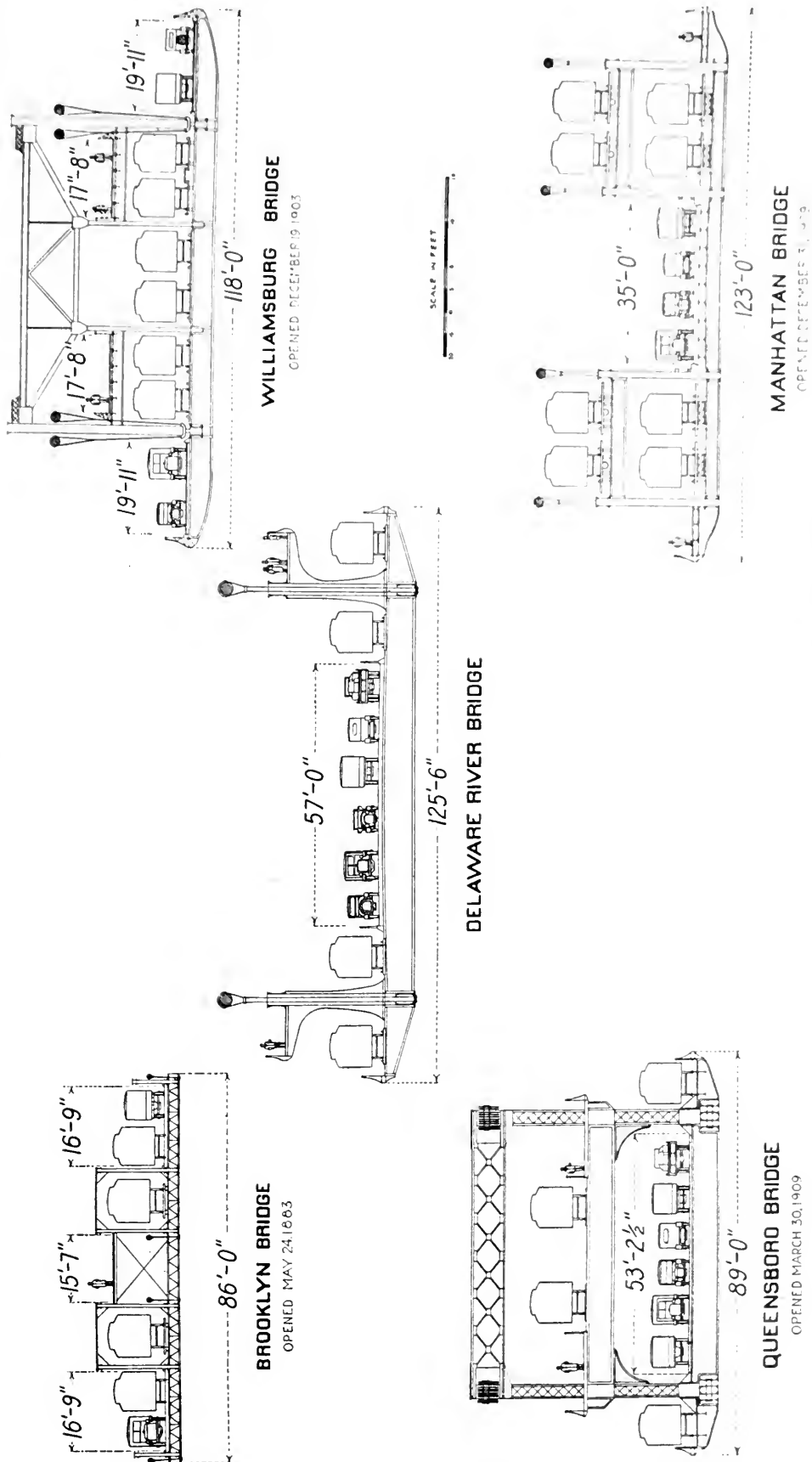
The arrangement of the side spans may either consist of viaducts independent of the cables, the latter simply connecting to the anchorage at a convenient distance, as in the Williamsburg Bridge, or they may consist of stiffening trusses suspended from the cables as in the Manhattan Bridge. The latter system has been adopted in the Delaware River Bridge, as more economical and presenting a better appearance.

The deck of the bridge is arranged to provide a single roadway for vehicles, 57 feet wide between curbs, two street car tracks and two rapid transit cars, all on approximately the same level. Above the rapid transit tracks will be two sidewalks, each 10 feet wide. The single roadway provides for six lines of vehicular traffic. It is evident that the capacity of a single roadway is much greater than that of two roadways of one-half the width. At certain hours of the day, the traffic will usually be much heavier in one direction than in the other. A single roadway of six-line width will permit four lines to go in one direction, the smaller return traffic taking only two lines. This could not be done if there were two separate roadways of three-line width only. This feature of the design was considered of vital importance in planning the arrangement of the deck. (Fig. 5.)

There are only two bridges in New York which have a single roadway, namely, the Manhattan Bridge, with a roadway 35 feet wide, and the Queensboro Bridge, with a roadway 53 feet 2½ inches wide. The 57-foot roadway of the Delaware River Bridge is only 3 feet narrower than Market Street, in Philadelphia. We have seen that the live load has been assumed at 12,000 pounds per lineal foot of bridge. This corresponds to the maximum or congested loading, and in order to reach that figure, the roadways would have to be loaded with automobiles and heavy trucks in close contact, the four tracks loaded with continuous lines of heavy type cars filled to capacity with passengers, and the sidewalks crowded at the rate of one grown person to every 3 square feet.

Such a loading is so improbable as to be almost impossible,

FIG. 5.

19'-11"

17'-8"

17'-8"

19'-11"

118'-0"

WILLIAMSBURG BRIDGE
OPENED DECEMBER 19, 1903

35'-0"

123'-0"

MANHATTAN BRIDGE
OPENED DECEMBER 31, 1909

SCALE IN FEET

57'-0"

125'-6"

DELAWARE RIVER BRIDGE

16'-9"

15'-7"

16'-9"

86'-0"

BROOKLYN BRIDGE
OPENED MAY 24, 1883

53'-2½"

89'-0"

QUEENSBORO BRIDGE
OPENED MARCH 30, 1909

Comparative cross-sections of five large bridges.

but should it occur, all parts of the bridge will carry it within very safe limits.

In the Delaware River Bridge the arrangement of the surface lines and rapid transit tracks was the subject of much study. It is planned to keep the entrance or approach plazas free from car tracks of any sort, also to avoid objectionable elevated structures near the plazas. This is accomplished by causing such tracks to ascend and descend at a steeper grade than the roadways and placing their terminals or connections under the surface grade of the plaza, in Philadelphia, and diverting them away from the plaza in Camden.

The reasons for locating the bridge at Franklin Square, Philadelphia, are fully set forth in the Board of Engineers' report to the Delaware River Bridge Joint Commission, dated June 9, 1921, and printed for distribution. It might be of interest, however, to state here how the Board went about to determine one of the principle factors, that of the centre of gravity of origin and destination of vehicular traffic on each side of the river. It was not possible in the limited time allotted to the preparation of the report to take a census of the traffic at various times of the year. The Board therefore chose three representative week days in December, 1920. Men were stationed in relays, day and night, at all the six lines of ferries between Philadelphia and New Jersey points. Each driver was asked to state where he started from, giving town, district and street corners, and also the point of his destination. In three days, 16,269 records were secured. These were plotted on maps, and from them were obtained the centres of origin and destination of the traffic. It is believed that fully 80 per cent. of the traffic was thus represented, the other 20 per cent. being of a kind not occurring in winter, such as produce from New Jersey, for instance. A straight line drawn between the centre in Philadelphia and the one in Camden would be the most economical route for the 80 per cent. of traffic. Such a line would come very near the foot of Market Street. A bridge at Market Street, however, could not be considered because, first, it would be inadvisable to turn more traffic into the already congested Market Street, and, second, because of the prohibitive cost of real estate to be acquired. The location which has been chosen is as near Market Street as consistent with reasonable cost and as physical conditions permit.

AERONAUTIC RESEARCH.*

BY

JOSEPH S. AMES, Ph.D., LL.D.

Professor of Physics, The Johns Hopkins University, Baltimore, Maryland; Chairman Executive
Committee National Advisory Committee for Aeronautics.
Member of the Institute.

PROGRESS in the navigation of the air is being made constantly along two quite distinct and independent lines; one is the art of flying and the other is the science of flight. To this last is given the name *aeronautics;* and by an aeronautical investigation is meant a research which has a direct bearing upon our knowledge of the properties of solid bodies immersed in a stream of air or moving through the air. We wish to know the forces and moments acting upon such solid bodies; how these vary with the shape and characteristics of the bodies, and how they are affected if the velocity of the air is changed. Another important inquiry refers to the stability of the solid body when in flight; if the attitude of the body is changed by some gust or otherwise, does it tend to return to its previous attitude, or on the contrary does it continue to depart more and more from its original attitude? The question is like that referring to a body balanced on a table. If it is pushed slightly, will it simply oscillate to and fro, or will it turn over? These matters and similar ones make up the subject of aeronautics; and in order to investigate them the same methods must be applied as in any department of physics.

Experiments must be performed; a theory is evolved; deductions are made from the theory and tested by experiment; the theory is modified and improved, etc. During all the process knowledge is being gained, and the facts being made known help the designer of aircraft to make improvements in speed, in carrying power, in safety, in stability.

One most important fact should be emphasized, and this is that without the series of scientific studies just outlined not only would flight itself have been impossible, but also all progress in the art would cease. Scientific investigation forms the most important feature of aviation, and it can be conducted only by trained

---

* Presented at the meeting of the Section of Physics and Chemistry held Thursday, October 6, 1921.

students. The best pilot in the world may know very little about the scientific principles underlying flight, and he would therefore be unable to make any marked improvements in his machine. Aeronautics is in no sense a function of an engineer or constructor or aviator, it is a branch of pure science. Those countries have developed the best airships and airplanes which have devoted the most thought, time and money to the underlying scientific studies. When the physical facts are known, the engineer can design his aircraft, the constructor can make it, and the trained man can fly it; but the foundation stone is the store of knowledge obtained by the scientist.

FIG. 1.
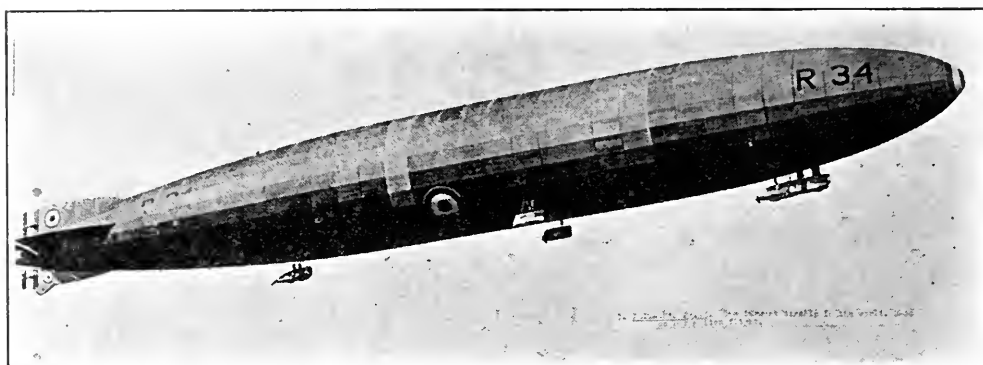
Airship, filled with hydrogen. Engines and propellers; elevators and rudder; stabilizing surfaces.

Before describing the types of investigations in progress in aeronautics and the methods pursued, it may be interesting to see some illustrations of the two types of aircraft now in use: The airship and the airplane. If I had time, I would like very much to say something about the helicopter, a type of aircraft to which we have given a name before constructing one. Up to the present no such machine, worthy of the name, has been made; but beyond a doubt one will be constructed, and in the near future.

An airship owes its flying power to the fact that it is made "lighter than air" by being filled with a gas lighter than air. Hydrogen is the gas always used, although helium may be. The lifting power of the latter gas is about four-fifths of that of hydrogen. As the airship moves through the air, it meets with opposition as the air flows along its surface. Forces are required to move the control surfaces, *i.e.*, the rudders and elevators. We

FIG. 2.
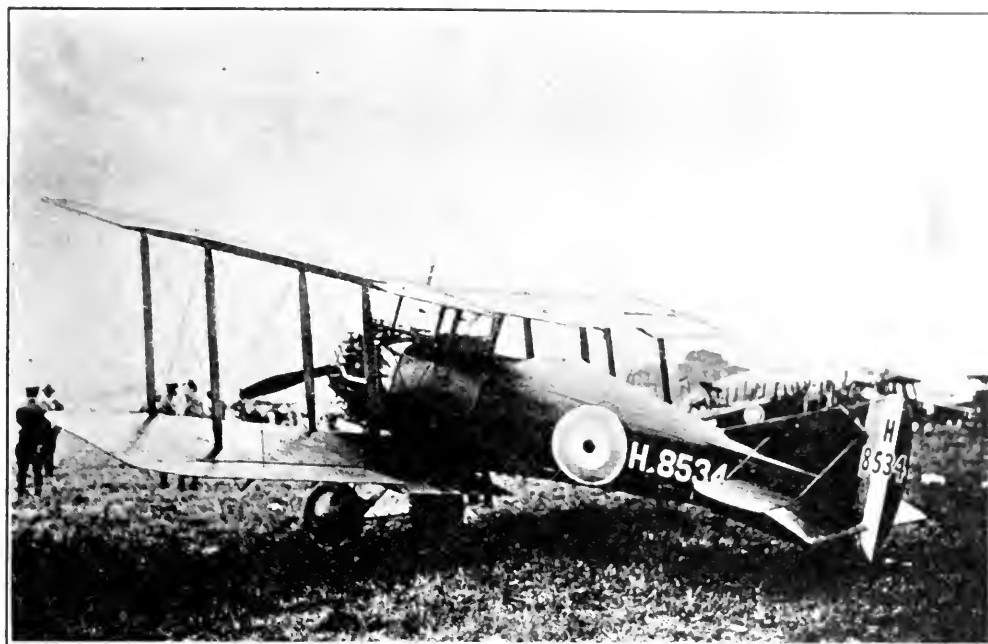
Airplane.   Wings, fuselage, ailerons, elevator, rudder, etc.

FIG. 3.

Fokker F. III.   Commercial monoplane.

must determine these forces, and must investigate the changes in
them as we change the shape of the airship, *e.g.,* its length or its
cross-section. A great deal may be learned by studying theo-

FIG. 4.
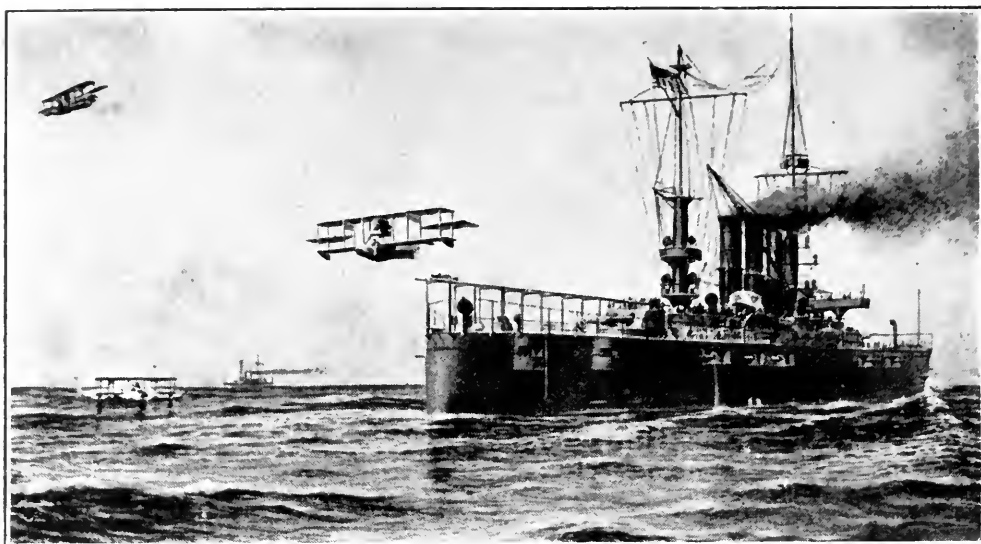
Airplane carrier. Seaplanes in flight.

FIG. 5.

Scale of Drawing
Inches 0 1 2 3
Pounds 0 .1 .2 .4 .6
Forces on Model of 30 miles per hour

Subscript indicates Angle of wing
chord to wind for corresponding Force, R
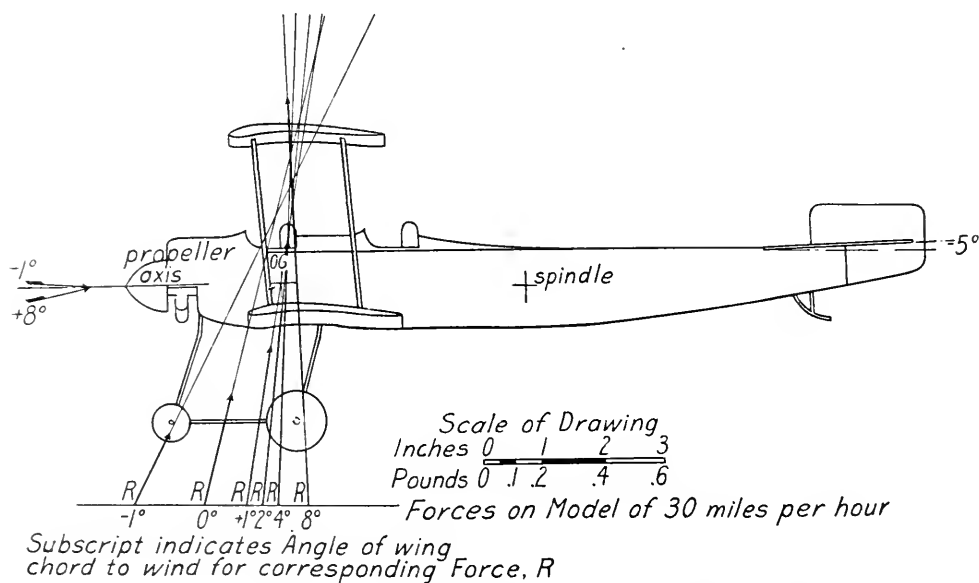
Drawing showing parts of an airplane model and the force-diagram.

retically the way in which air flows around a solid body shaped
more or less like an airship. A most interesting mode of attack
on this problem was devised by Admiral Taylor of our Navy, and

FIG. 6.
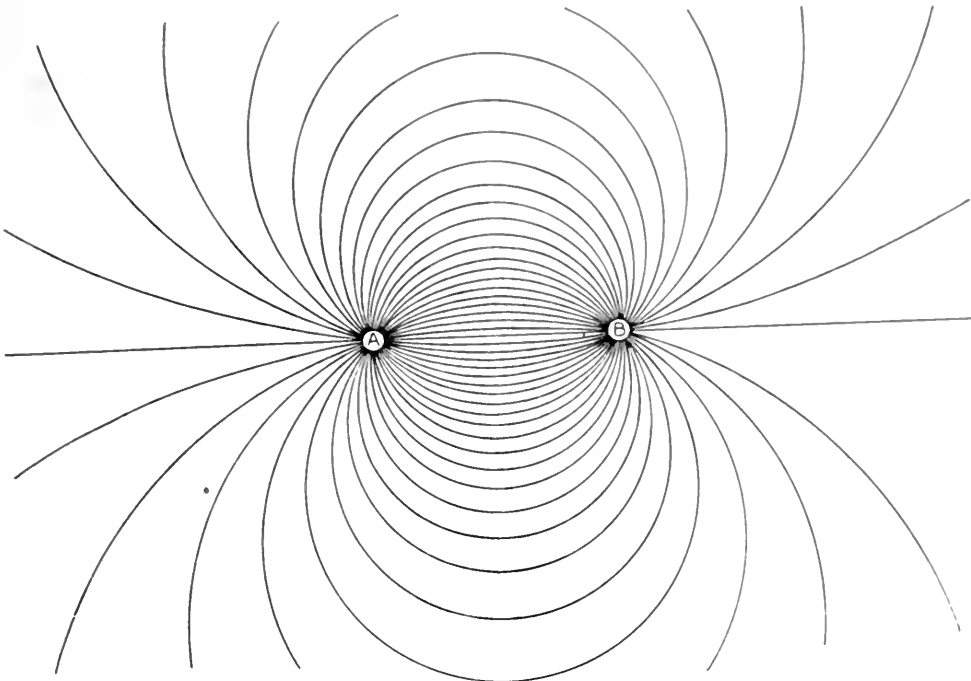
Combination of source and sink.

FIG. 7.
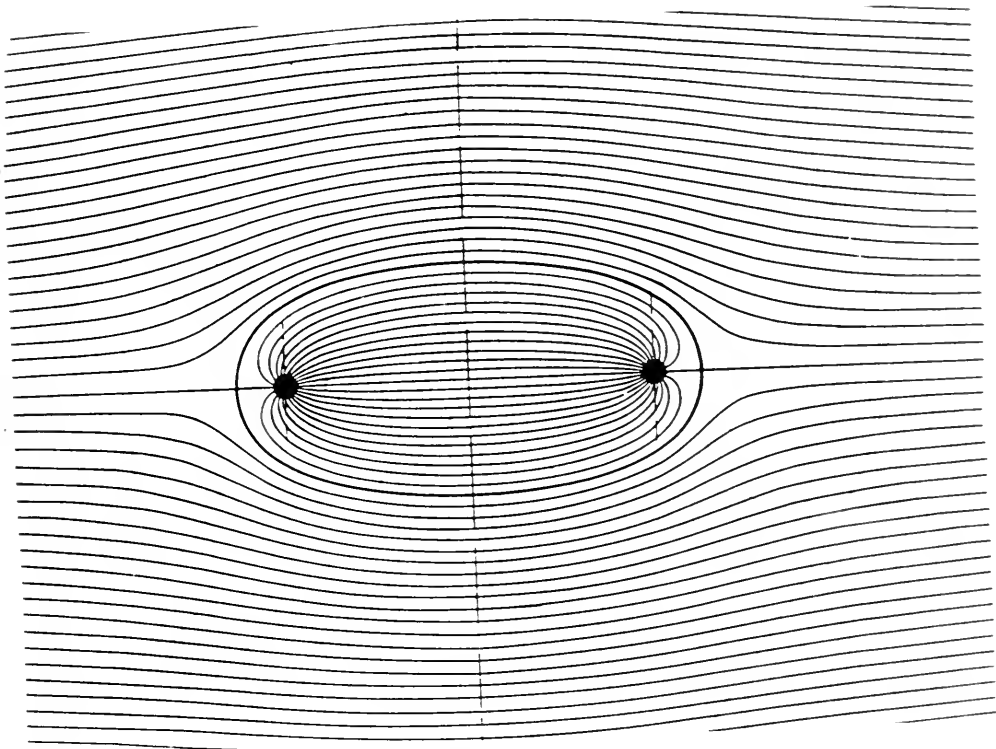
Air flow due to superposing a uniform rectilinear flow upon a combination of source and sink.

was applied by him to the design of ocean vessels. The drawings illustrate how a uniform flow superposed upon a source and sink produces a condition like the flow around an airship. This

FIG. 8.
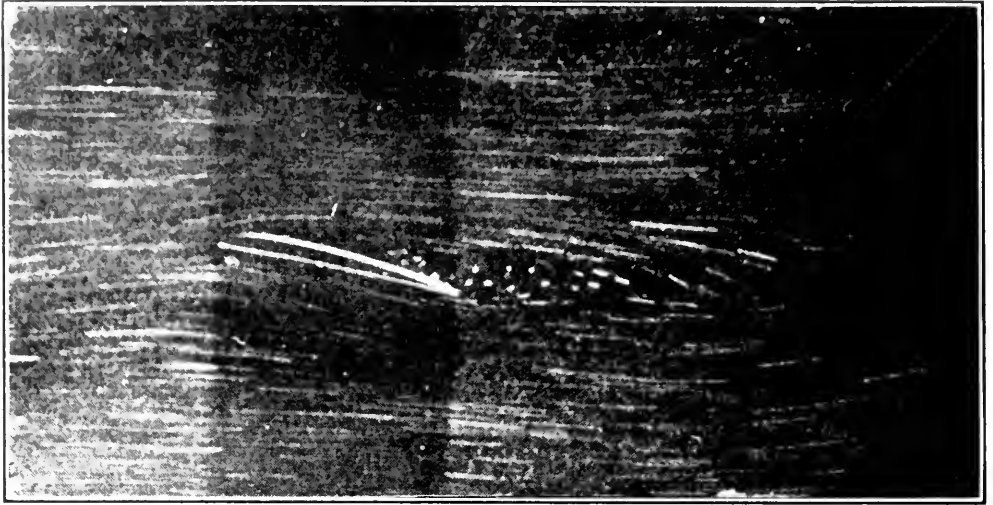
Eddying flow past an aerofoil.

FIG. 9.
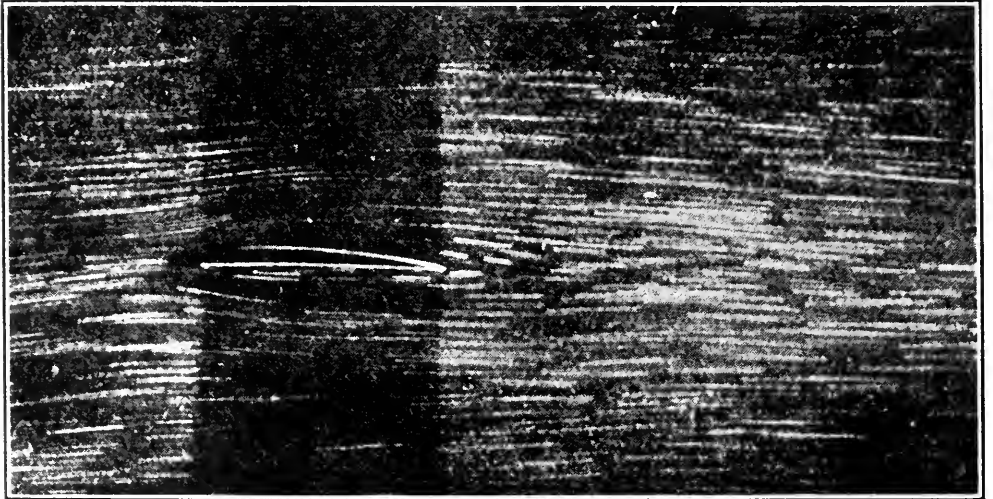
Stream-line flow past an aerofoil.

type of flow may then be studied mathematically; the pressures may be deduced, etc.

Similarly, in the case of airplanes, we must know the character of airflow past the struts, the fuselage and the wings. It is the difference in the pressure on the two sides of a wing that produces

the upward force required to support the machine. The figures illustrate the type of flow around an aerofoil.

Great progress has been made in recent years by Prandtl and other German physicists by showing how a flow of air around an aerofoil could be produced in an ideal frictionless gas similar to that observed in air, by imagining vortices or whirls in the gas. The method is not unlike that mentioned above as useful in the case of airships, only vortices are used in place of sources and sinks. Following this process Prandtl and his associates have shown how one could calculate the influence of one wing of a

FIG. 10.
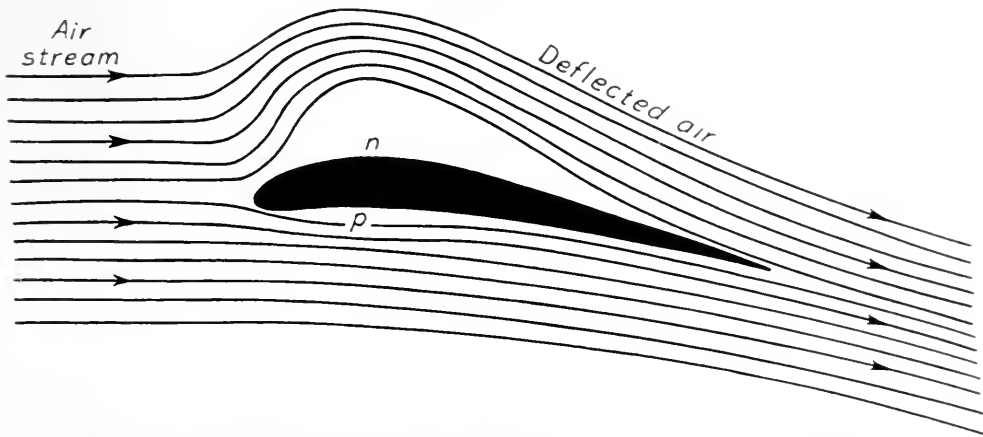
Diagram of flow past an aerofoil showing an increased pressure below and a decreased one above.

biplane upon the other; so that if the behavior of one wing is known that of two may be deduced; and they have proceeded much further and made aeronautics into a beautiful theoretical science.

But in the end the function of aeronautic research is obviously to learn all there is to be known about the forces acting on an aerofoil or wing. How can this be done? It is not possible to make actual airplanes of various types and test them, nor would this help us much if it were practicable. We must actually measure the forces involved in any one case, and must vary our conditions in every conceivable way, but in a systematic manner. There are several methods open to us. One is to make a model of a wing, say, as nearly full size as possible, suspend it by wires 30 feet or more below an airplane which can carry it in flight, and then, by inserting measuring instruments in the wires study the forces under varying conditions. This method is being used with marked success at Langley Field, near Old Point Comfort, Virginia, by

the staff of the National Advisory Committee for Aeronautics. It is called the " free-flight method."

A second method is to make a small model of a wing or a fuselage or an entire machine, say one twenty-fifth the size of the

FIG. 11.
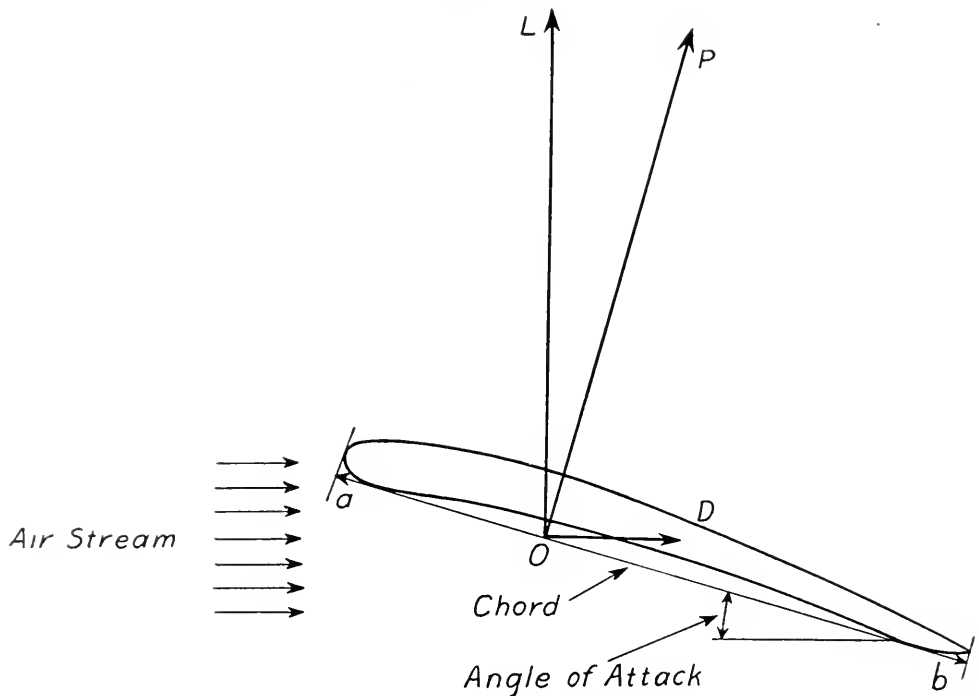
Diagram illustrating forces acting on an aerofoil.

FIG. 12.
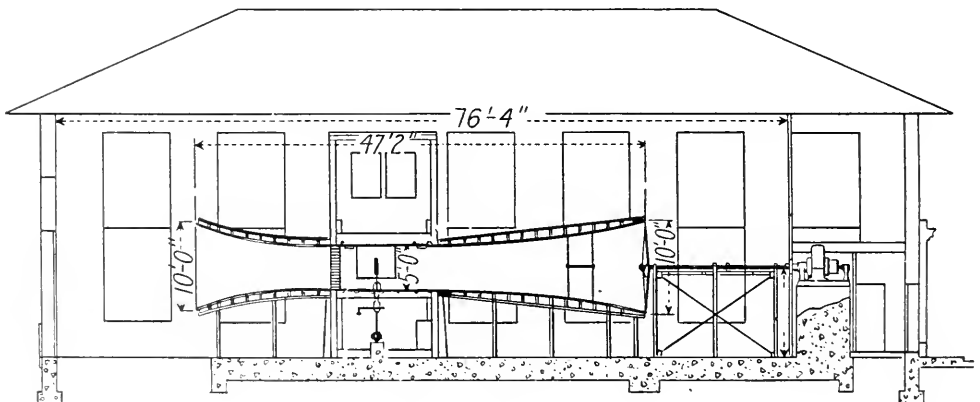
Diagram of wind-tunnel in its house.

actual part, and then to investigate the forces acting on it when it is placed in a rapidly moving stream of air. This is known as the wind-tunnel method, and is now in general use in all countries. England has ten or more such tunnels, France has several, Ger-

many has a large number, etc. In this country there are twelve, and more are being made.

Other methods have been used in the past, but are no longer. Langley attached his models to one end of a long arm which could be made to revolve rapidly in a horizontal plane. Others have

FIG. 13.
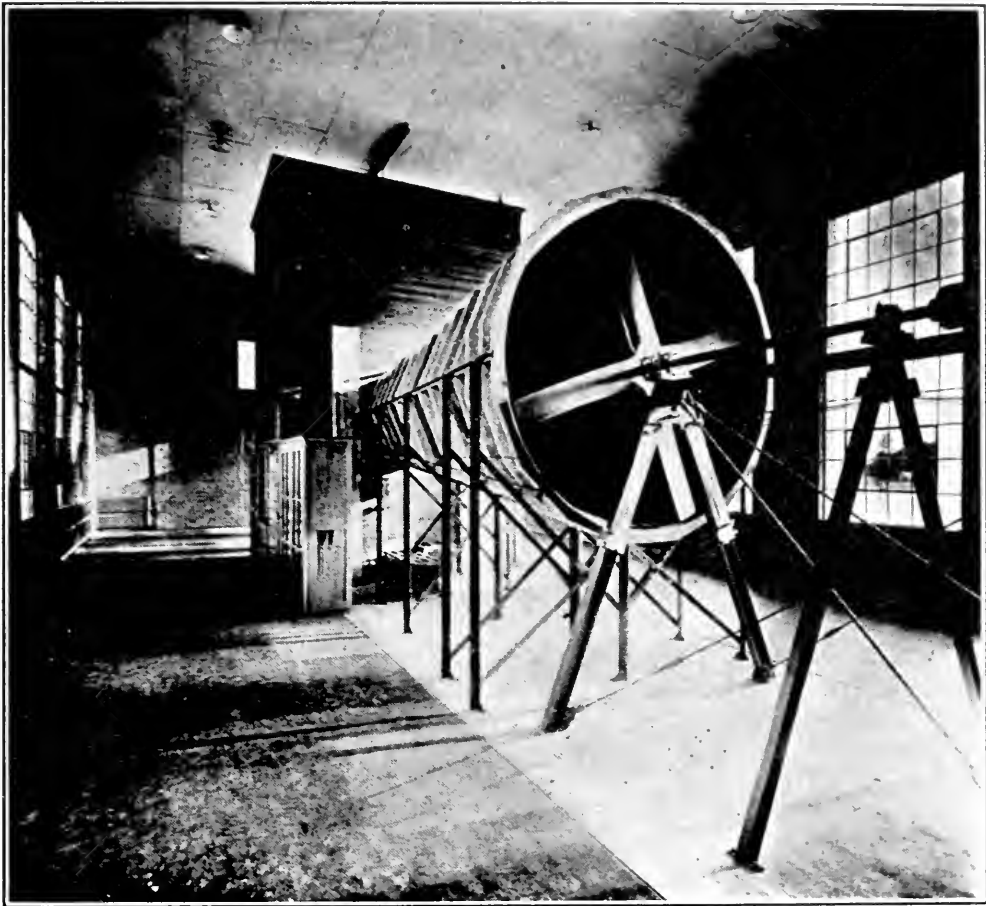
Exterior of tunnel, from exit end.

studied models of different shapes by dropping them from heights inside buildings, so as to avoid wind.

Owing to the importance of wind-tunnels, I will show some photographs of the latest one made in this country, that of the National Advisory Committee for Aeronautics at the Langley Memorial Laboratory, Langley Field, Virginia.

Investigators in these different laboratories all over the world have studied the greatest variety of problems: Forces on models of wings of different shapes at different air velocities, forces on

models of airships, the effect of disturbing elements on these forces, etc. A long series of investigations has been made in particular upon air propellers. The blade of a propeller may be con-

FIG. 14.
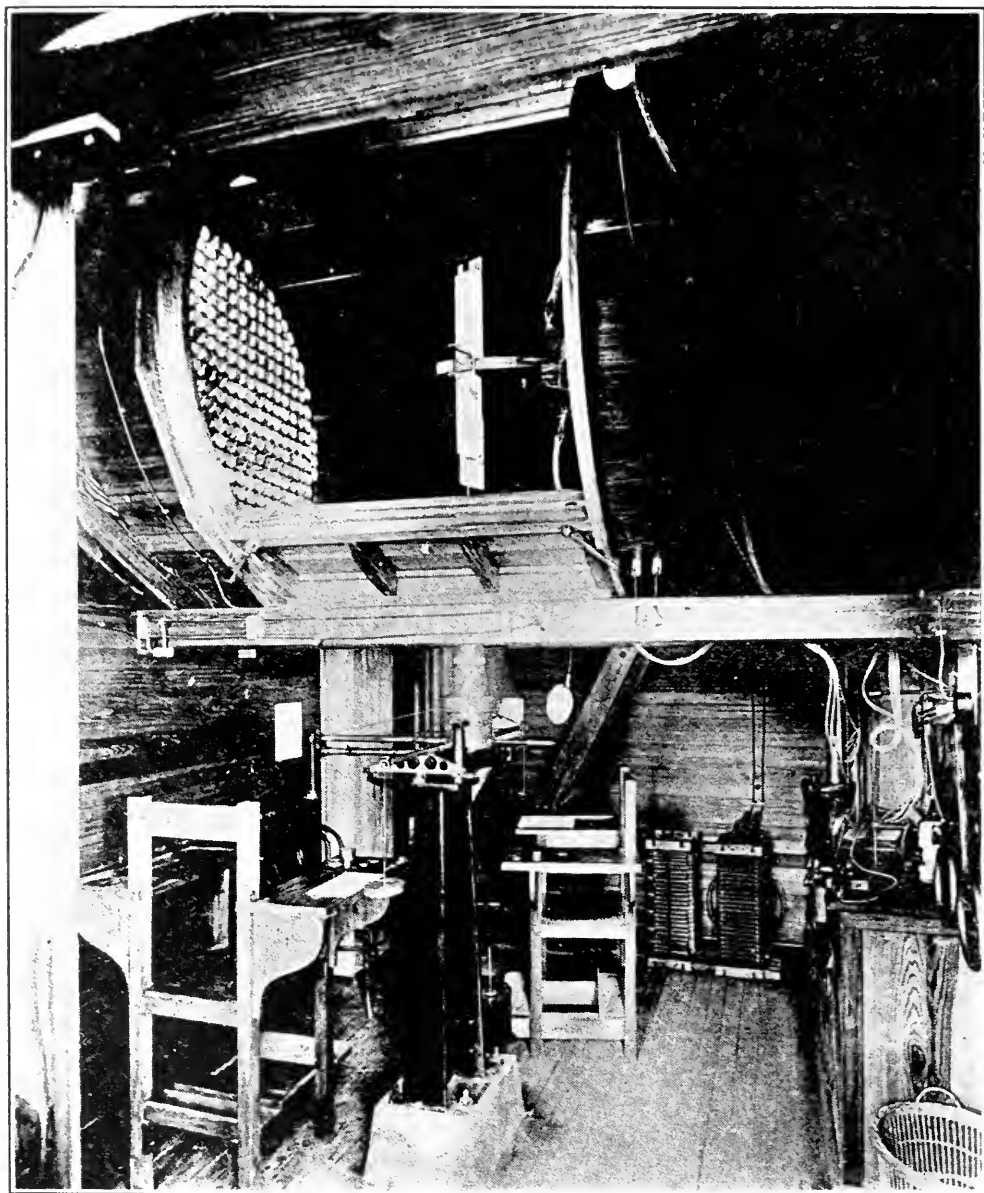
Interior of experimental room and view of model suspended in tunnel.

sidered as made up of a number of separate surfaces; and, when the shaft is rotating, each of these is thought of as an aerofoil moving rapidly through the air. In this way the action of a pro-

peller may be calculated, and the theory may be tested by trying the actual propeller. But there is one all-important difficulty in applying the knowledge thus available to the design of actual aircraft. Is one justified in drawing conclusions as to the properties

FIG. 15.
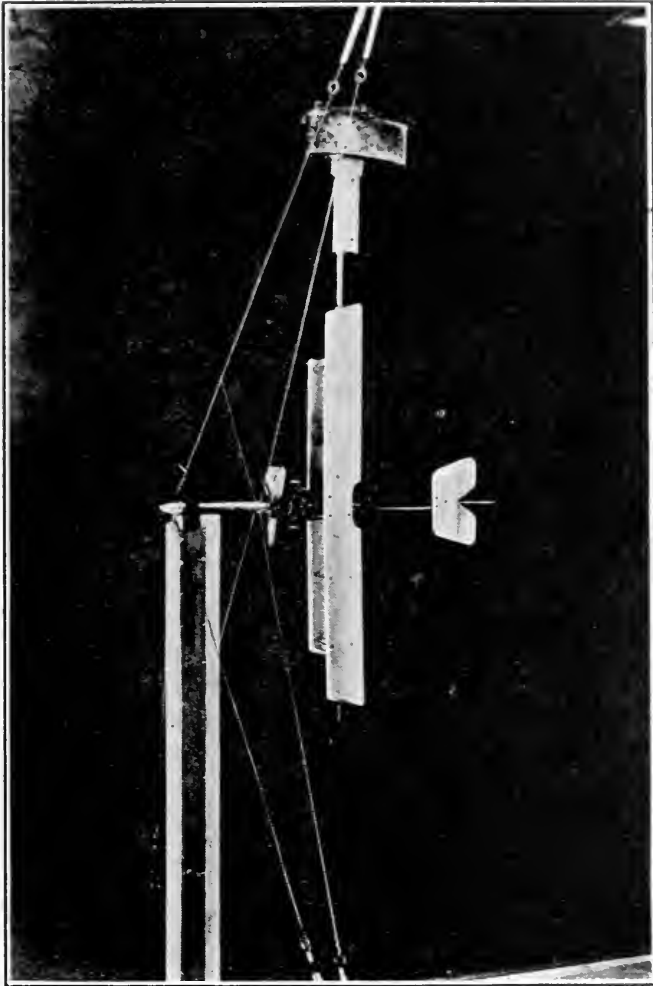
Model of a biplane.

of large bodies from knowledge of the properties of smaller ones? Suppose, for instance, that on comparing two models, on a scale of one twenty-fifth of full size in a wind-tunnel through which the velocity of the airstream is 40 miles per hour, it is found that one model has a greater lift or a less drag than the other, what conclusion could one draw as to the comparative properties of two actual airplane wings in flight at 120 miles per hour? The answer is,

VOL. 193, No. 1153—3

" possibly none." The exact condition in order that results from tests on models may be applied to actual construction is known. This can best be described by discussing what is called in aero-

FIG. 16.
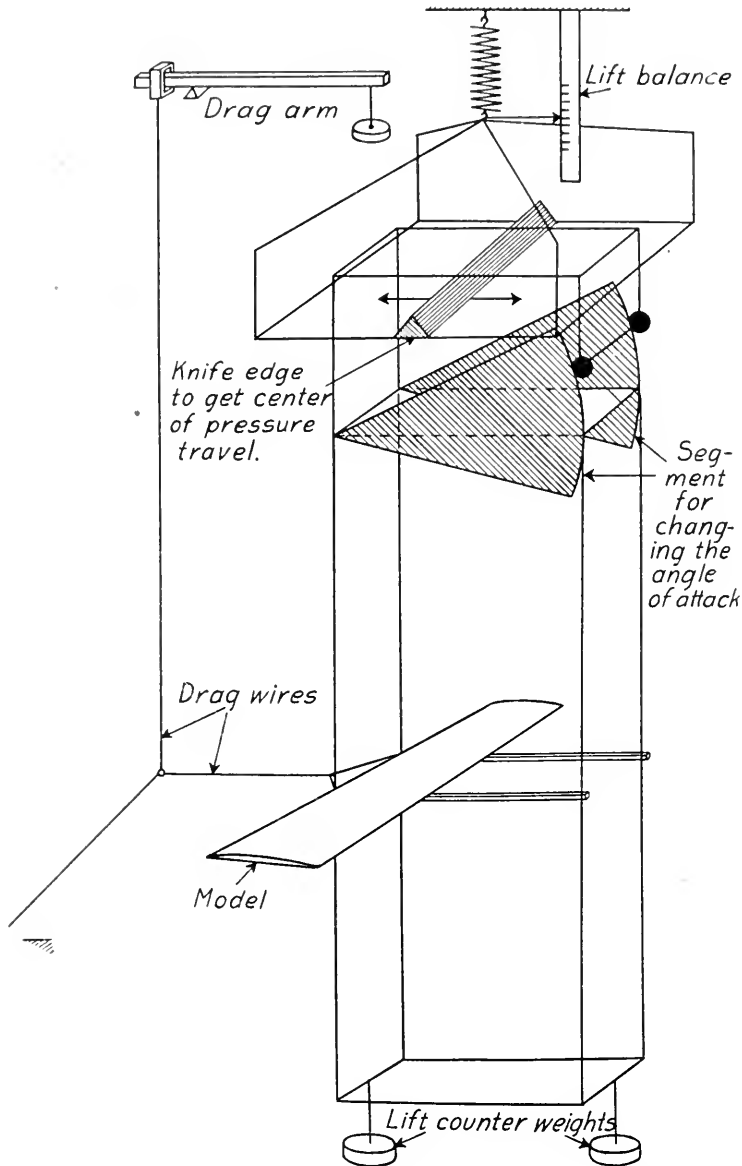
Scheme of the balance used to measure the forces on a model.

dynamics the " Reynolds number." When a body is moving through the air there are two types of forces acting on it: The air exerts a pressure upon it and there is friction between the moving air and the layer of air sticking tight to the solid. It is not difficult to see that the four physical quantities involved in the

aerodynamical action are: The velocity of the air, its density, its viscosity (*i.e.*, measure of the frictional property) and the size of the solid body as given by its length or its thickness. Lord Rayleigh showed many years ago that, if we formed the quantity

$$\frac{density \times velocity \times length}{viscosity}$$, which is now called the " Reynolds

number," we would be justified in saying that the properties observed in any experiment would also be found to be the same for any other experiment having the same Reynolds number. It is seen by looking at the definition of this number that we can have the same Reynolds number for a large number of different experi-

FIG. 17.

Compressed air wind-tunnel.
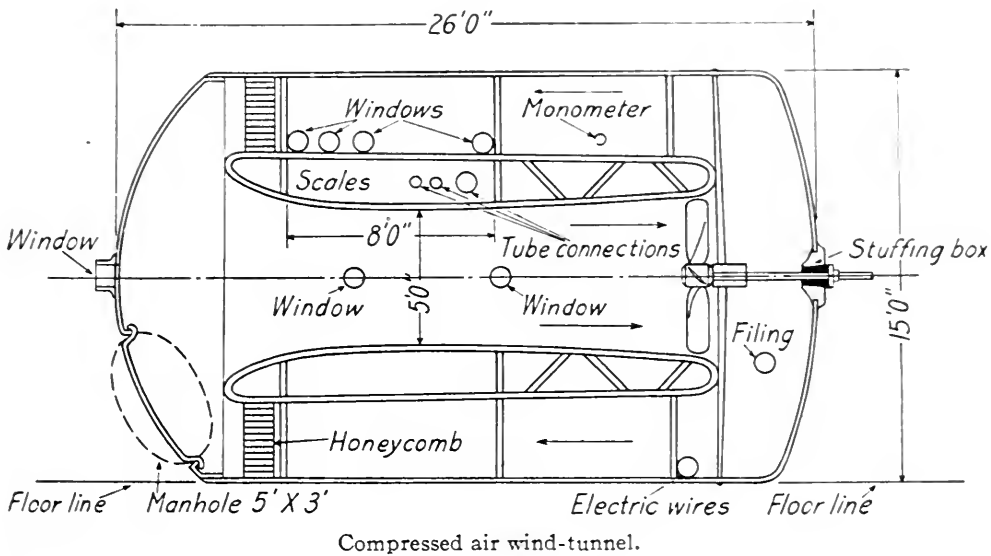
ments. Thus compare an actual airplane in flight at 90 miles per hour say, with a wind-tunnel experiment on a model of one-twentieth scale but having the same velocity of airflow. If the Reynolds number is to be the same for the two cases, it is necessary to increase the density of the air in the wind-tunnel twenty-fold. This shows that if one were to make a wind-tunnel in which the air is compressed to twenty or more atmospheres, experiments on models placed in it would give results immediately applicable to full-sized airplanes. It is perfectly possible, of course, that certain properties studied and observed in ordinary wind-tunnels at atmospheric pressure may hold also for actual airplanes; but one cannot be certain of this until the question is investigated in a compressed air tunnel. In view of the great importance of this matter,

the National Advisory Committee for Aeronautics has designed and has now under construction such a tunnel in which the air may be compressed to 25 atmospheres. When completed, it will be the only one in the world; and it is expected confidently that a great amount of useful information will be obtained.

I have outlined the experimental methods available for aeronautical investigations, and wish now to state briefly some of the more important ones which occupy our thoughts.

1. Every one, the world over, is interested in designing a helicopter; but before this can be done we much have knowledge of the properties of a propeller whose shaft is very oblique to the flight path, and we probably shall have to design a new type of propeller.

2. A greater range of speed for any one airplane is desirable, so that it may attain a great flying speed and yet have a slow landing speed. In order to secure this possibility, modifications of the wing are essential; and the most promising form at the present time is the Handley-Page slotted wing. Much more research is, however, necessary.

3. Great improvements may be expected in reducing the drag, or resistance, of aircraft, and many researches are now in progress as to the effect of putting the engine and propeller in different positions, of changing the position of the fuselage, etc.

4. Over 100 different wing forms have been investigated, but our practical knowledge is far from satisfactory, largely owing to the fact that the tests have been made in different laboratories and at different air velocities. Further, of course, the Reynolds number in all tests has been too small. When the compressed air wind-tunnel at the Langley Memorial Laboratory is finished, we will be able definitely to say what wing is best for any specific purpose.

These are simply illustrations of the type of investigations now engaging the attention of aeronautical laboratories, but they serve, I hope, to make clear how interesting the subject is to the scientist and how important to the designer of aircraft.

CHEMICAL ASPECTS OF VOLCANISM WITH A COLLECTION OF THE ANALYSES OF VOLCANIC GASES.*

BY

E. T. ALLEN, Ph.D.

Chemist, Geophysical Laboratory, Washington, D. C.

I. INTRODUCTION.

VOLCANOLOGY like other branches of geology is a subject of many phases enlisting the services of many sciences. Chemistry is chiefly concerned with the more active stages.

The peculiar inaccessibility of the active volcano, its remoteness in many cases and the intermittent character of its processes have conspired to limit opportunities of observation and have therefore greatly retarded the progress of the subject. It is as yet hardly entitled to be called a science. The limited opportunities for observation have naturally compelled the student to depend in large measure on the observations of others. Furthermore, it is eminently true of so complex a subject that tentative conclusions arrived at by any special train of reasoning must be examined in the light of many different sciences before they can become generally acceptable. Every contributor to it must therefore be aware of the fragmentary character of his work.

A comprehensive consideration of volcanology in its chemical aspects would include at least a discussion of the magma, of the influence of the composition of lavas and especially the volcanic gases on intrusive and eruptive phenomena, and the part played in these phenomena by chemical energy. Present knowledge permits us to go but a short way along any of these paths.

II. NATURE AND ORIGIN OF THE VOLCANIC GASES.

Chamberlin and Salisbury [1] say: " It is one of the outstanding problems in geology to determine the origin of the volcanic gases." As a first step in the solution of this problem we shall endeavor to determine what the original gases are through a discussion of

---

* Presented at a meeting of the Section of Physics and Chemistry held Thursday, December 1, 1921.

[1] "Textbook of Geology," vol. i, p. 592. (New York, 1904.)

the constituents of these gaseous mixtures as they occur in the field, their chemical characteristics and the field conditions which may have influenced them.

I. Integrity of the gases studied; possible changes in the composition of original gas mixtures.

(1) *By Addition of Air.*—Volcanic gases as collected in the field generally contain oxygen. In some instances field conditions such as low gas pressure in a vent, or a large surface opening within which gases issue only at certain points, are practically sure to result in atmospheric contamination and some methods of collection necessarily involve admixture of air; but even when the conditions of collection exclude errors from sources of this sort the quantity of oxygen may still be considerable, amounting occasionally to as much as 20 per cent. It is safe to say that this oxygen was not derived from the original magma, for that portion of it which was not retained by combination with ferrous oxide would surely be reduced to a negligible quantity by the combustible gases contained in it—hydrogen, carbon monoxide, etc.—inasmuch as their oxygenated products, water and the dioxide of carbon are only weakly dissociated at the temperatures which molten lavas are known to attain. The oxygen is therefore in all probability exotic, originating presumably in the air which in some way finds access to the gaseous conduits below the surface of the ground. The hypothesis is that air is drawn through pores and crevices of the conduits or fumaroles by the suction of the hot rising gases. The manner of access is difficult if not impossible to prove, but the contamination by air is substantiated by other evidence.

(a) *Significance of the Relations Between the Inert Gases.*—Fumarole gases collected in 1919 in the Katmai region, Alaska, and studied by E. G. Zies [2] and myself, were found to contain nitrogen and argon in very nearly the same proportion to each other that is found in the air. The average percentage of argon in the inert gas was 1.25, while in the atmosphere it is 1.18. The inference was that these constituents of the fumarole gases came chiefly from the air along with oxygen which had been largely, but not entirely, removed by chemical reactions occurring partly outside the fumaroles, and partly in the fumaroles themselves; while the inert nitrogen and argon remained in their original proportions. The highly porous nature of the pumiceous deposit

[2] Unpublished.

in which the Katmai fumaroles occur affords easy access to air and thus partially substantiates the hypothesis.

Our conclusion was the natural, but not the only one. The French scientist, Moureu, has examined with care a large number of natural gases. He states that in all of them the relations of all the inert gases to one another except helium are sensibly the same as they are in the air, and he concludes from his results that these constituents originated in the primordial atmosphere of the globe, and that because of their inert chemical nature they have remained uncombined and in virtually the same proportions to this day. Moureu's [3] investigations were confined chiefly to spring gases and mine gases; only one volcanic gas was included. When we seek further evidence on these relations we find that most recorded analyses of volcanic gases do not include argon. Gautier,[4] in two samples, one from Vesuvius and one from Lago d'Agnano near Naples, found the percentage of argon in the inert gases nearly the same as in the atmosphere. Moissan [5] also, in a gas from a fumarole on Mt. Pelée, Martinique, found a similar percentage, 1.28. In two samples of gas from fumaroles in Guadeloupe, however, the same chemist obtained higher results, viz., 1.98 and 2.96. Porlezza and Norzi [6] obtained 1.78 per cent. in the soffioni of Larderello, Italy.

E. S. Shepherd [7] has examined many samples of volcanic gases from Kilauea and two from Mauna Loa. In most of the samples the ratio of argon to the total inert constituents is much higher than it is in the atmosphere, and generally indeed above 3 per cent., but a few samples contain no argon at all. Strangely enough, the argon does not vary all the way between the limits; only one value occurs between zero and 1.96. These results are obviously at variance with Moureu's hypothesis.

The gases collected from the crater of Kilauea in 1912 by Day and Shepherd [8] probably came nearer representing true mag-

[3] Moureu and Biquard, *Compt. rend.*, 143, 180, 1906. Moureu and Lepape, *Compt. rend.*. 149, 1171, 1909; 152, 934, 1911; 153, 740, 847, 1043, 1911; 155, 197, 1912; 171, 941, 1920.

[4] *Compt. rend.*, 148, 1708, 1909; 149, 84, 1909.

[5] *Compt. rend.*, 135, 1085, 1902; 138, 936, 1904.

[6] *Atti Acad. Lincei*, 20, ii, 338, 1911.

[7] *Bull. Hawaiian Volcano Obs.* vii. No. 7, July, 1919; viii. No. 5, 1920.

[8] *Bull. Geol. Soc. Amer.*, 24, 573, 1913.

matic gases than any other samples that have been collected. Yet
if we accept the conclusions of Jaggar,[9] respecting the lava lake
of Kilauea, air is being continually carried down by convection
from the surface to the deeper layers of the magma; the oxygen
is entrapped in viscous but vesicular lava blocks at the surface,
probably combines rapidly with the ferrous iron of the lava and is
consumed at lower levels in the oxidation of portions of the mag-
matic gases. Consequently some of the nitrogen and its congeners
may come from the atmosphere. Respecting the relation of argon
to nitrogen one might therefore conclude, either that the gases of
Kilauea are all magmatic and variable in composition or that the
inert constituents of some samples are wholly or partly of atmos-
pheric origin and that some nitrogen as well as oxygen has been
absorbed by the lava. In any case the magmatic gases must be
highly variable.

This line of work deserves to be pursued further with the
purpose of finding whether the relations of the inert gases can be
regarded as a criterion for the magmatic origin of these con-
stituents in volcanic gases. The data on this point so far as they
could be found are tabulated in Table I.

(2) *By Addition of Volatile Products from Outside Sources.*
—So far as known, rocks of all kinds give off some gas when
they are heated. Rocks which are subjected to volcanic intrusion
may therefore be expected to give off gases. The gas which will
be driven off in the largest quantities is steam, for nearly all rocks
contain water, and it requires only a moderate temperature to
drive out the greater part of it. The carbonates of calcium, mag-
nesium and iron are easily dissociated, giving carbon dioxide; and
the sulphides in general either by thermal dissociation or by well-
known reactions with water or air give, at no very high tem-
peratures, sulphur, hydrogen sulphide or sulphur dioxide, according
to prevailing conditions. Bituminous shales and similar materials
when heated are certain to give the products of dry distilla-
tion—hydrocarbons, especially marsh gas, carbon dioxide, am-
monia and tarry matter. While such reactions are sure to be
induced under certain conditions, carbon dioxide, marsh gas and
ammonia are common volcanic emanations occurring in many
places where there is no positive evidence of the presence of lime-
stones, sulphide deposits or organic materials. From general con-

[9] *Bull. Seismolog. Soc. Amer.,* x, 155, 1920.

TABLE I.

Relation of argon to the total inert constituents of volcanic gases.

No.	Locality	% N_2	% A	$\frac{A}{A + N_2} \times 100$
1	Mt. Pelée, Martinique	54.94	.71	1.27
2	Guadeloupe, W. I.	36.07	.73	1.98
3	Guadeloupe, W. I.	22.32	.68	2.96
4	Larderello, Italy	1.35	.0245	1.78
5	Vesuvius	17.62	.243	1.36
6	Lago d'Agnano, near Naples	2.87	.028	.99
7	Kilauea, T. H.	12.88	.45	3.38
8	Kilauea, T. H.	3.50	.07	1.96
9	Kilauea, T. H.	5.88	.18	2.97
10	Kilauea, T. H.	.87	.14	13.87
11	Kilauea, T. H.	8.92	.29	3.15
12	Kilauea, T. H.	2.44	.39	13.78
13	Kilauea, T. H.	2.37	.56	19.11
14	Kilauea, T. H.	2.33	.00	.00
15	Kilauea, T. H.	20.01	.00	.00
16	Kilauea, T. H.	2.41	.14	5.4
17	Kilauea, T. H.	15.03	.21	1.3
18	Kilauea, T. H.	4.13	.31	6.9
19	Kilauea, T. H.	.68	.05	6.8
20	Kilauea, T. H.	3.35	.66	13.9
21	Kilauea, T. H.	2.91	.00	.00
22	Kilauea, T. H.	6.20	.16	2.5
23	Kilauea, T. H.	3.11	.08	2.5
24	Kilauea, T. H.	1.29	.04	3.0
25	Kilauea, T. H.	4.50	.12	2.6
26	Mauna Loa, T. H.	16.80	.58	3.34
27	Mauna Loa, T. H.	15.39	.42	2.66
		cc N_2	cc A	$\frac{A}{A + N_2} \times 100$
28	Katmai Region, Alaska	23.91	.31	1.28
29	Katmai Region, Alaska	26.34	.29	1.09
30	Katmai Region, Alaska	7.42	.09	1.20
31	Katmai Region, Alaska	26.65	.42	1.55
32	Katmai Region, Alaska	4.45	.05	1.11
33	Katmai Region, Alaska	175.90	1.984	1.11
34	Katmai Region, Alaska	20.36	.26	1.26
35	Katmai Region, Alaska	8.31	.10	1.15
36	Katmai Region, Alaska	21.25	.32	1.48

Nos. 1, 2, and 3 made by Moissan, *Comp. rend.*, **135**, 1085 (1902); **138**, 936 (1904).

No. 4, made by Porlezzi and Norzi, *Atti. Acad. Lincei*, **20**, II, 338 (1911).

Nos. 5 and 6, made by Gautier, *Comp. rend.*, **148**, 1708 (1909) (argon in 5 by Moureu; **149**, 84 (1909).

Nos. 7–27, made by Shepherd, *Bull. Hawaiian Vol. Obs.*, **7**, 94 (1919); **8**, 65 (1920); **9**, 86 (1921).

Nos. 28–36, made by Allen and Zies, unpublished.

TABLE I.—*Continued.*

No.	Locality	% N₂	% A	$\frac{A}{A + N_2} \times 100$
37	Iceland Reykir No. 1	98.49	1.48	1.48
38	Iceland Reykir No. 2	98.36	1.60	1.60
39	Iceland Reykir No. 5	98.34	1.61	1.61
40	Iceland Hveravellir No. 2	16.50	.294	1.75
41	Iceland Hveravellir No. 25	20.6	.441	2.10
42	Iceland Grafarbakki No. 1	90.0	1.68	1.83
43	Iceland Grafarbakki No. 2	93.4	2.15	2.25
44	Iceland Laugaros No. 1	97.4	1.93	1.94
45	Iceland Laugaros No. 3	97.4	2.10	2.11
46	Iceland Reykjafoss No. 1	67.9	1.36	1.96
47	Iceland Hengill No. 1	1.8	.0113	.62
48	Iceland Hengill No. 3	3.9	.088	2.21

Nos. 37–48 made by Thorkelsson, *Mem. Acad. Royal de Danemark*, 8, 182 (1910).

siderations it seems more than likely that emanations of this sort are generated in the early stages of an eruption if at all and that they should, at any rate, decline during long periods of eruptive activity.   (T. C. Chamberlain.)

(3) *By Fixation and Removal of Original Acid Gases Through Chemical Reaction.*—In the study of the gases from the Katmai fumaroles [10] we found that hydrochloric acid and hydrofluoric acids were of general occurrence and that their concentrations were comparable to those of carbon dioxide and nitrogen, respectively. In vents of low temperature (around 100°) the quantity of the acid gases was always small and this agreed with qualitative tests in the field.   It was also a conspicuous fact that the saline incrustations caused by the acid gases were almost entirely wanting about vents of low temperature.   Unfortunately the samples of gas from the hotter fumaroles were not collected under conditions which made it possible to establish any *quantitative* relation between temperature and acid concentration, but the results as they stand show that the concentration of acid is low when the temperature is low.

Our explanation of this phenomenon is quite a simple one. The Katmai fumaroles are usually lined with a coating of oxide of iron, probably for the most part derived from the minerals of the pumice from which the gases issue, but perhaps to some extent by an indirect process from deep-seated emanations.   Ferric oxide reacts with the halogen acids, giving the corresponding salts and

[10] Allen and Zies, *loc. cit.*

water. $Fe_2O_3 + 6HCl \rightleftarrows 2FeCl_3 + 3H_2O$ and $Fe_2O_3 + 6HF \rightleftarrows 2FeF_3 + 3H_2O$.   Both these reactions proceed from right to left with absorption of heat,[11] consequently the higher the temperature, other conditions remaining the same, the greater should be the proportion of acid in the gases.   Supposing then that a mixture of halide and oxide of iron in the walls of the fumaroles was swept by an equilibrium mixture of steam and hydrochloric acid gas, there would be neither gain nor loss in the concentration of acid in the gaseous phase and the concentration would be fixed by the temperature.   There is no certainty that the rushing gases actually adjust themselves to an equilibrium with the solids, and furthermore the percentage of water vapor is so very great in all the Katmai gases that it may surpass the equilibrium pressure at the *highest* temperatures so that none of the acid is fixed, but at *lower* temperatures the present imperfect data permit the hypothesis that the equilibrium pressure of acid is there so low that more and more acid is fixed with falling temperature.   As stated above, the Katmai fumaroles of low temperature are exhaling comparatively little acid and forming as a rule no saline incrustations about the vents.   Those vents which are lined with oxide of iron were probably once hotter than now, while those which contain none probably were never very hot; most of the gases, presumably, having been fixed by reactions taking place below the limit of our vision.   The acids may not confine their attack exclusively to oxide of iron; other oxides, more especially alumina, have been, and perhaps still are being, liberated from the minerals in the walls of the fumaroles by the combined action of the steam and acids just as the oxide of iron has been liberated.   Whether the hypothesis is correct or not, we find in the Katmai fumaroles a connection, though imperfectly worked out, between the temperature of the vents and the concentration of the strong acid gases which issue from them.   Though we have not the data to show it, the readiness with which hydrogen sulphide reacts with ferric oxide makes it practically certain that some of this gas is also removed and fixed by chemical reactions of this kind, and the same statement holds good for sulphur dioxide where that is an original gas.

(4) *By Addition of Water of Surface Origin.*—We have seen that water in surface rocks may be driven out by the heat of a volcanic intrusion.   The same is true of ground water.   Consider-

---

[11] According to Le Chatelier's principle.

able water is probably always expelled by a lava stream from the ground beneath it, and the steam thus formed may be mingled with the gaseous emanations from the lava.

Lacroix [12] has given excellent evidence for the existence at Martinique of secondary fumaroles or " fumaroles without root " which he regards as the result of surface water acting on hot volcanic detritus. The water is vaporized by the heat, and the steam reacts chemically with the detritus forming small amounts of the volcanic gases.

On the other hand, many of the fumaroles of the Katmai region [13] are so long-lived, so hot and so definitely related to surface fissures that we have regarded them as primary in the sense that some of the gases at least are thought to be rising directly from hot lava. Yet even here there is strong evidence of the dilution of the original gases by steam from surface sources. In all these fumaroles, so far as examination goes, water is the preponderating constituent, ranging from about 98.5 to 99.85 [14] per cent. by volume. The water was determined by condensing and measuring the quantity of it which accompanied a measured amount of fixed gas. When we express this quantity as the ratio between the volumes of *liquid* water and fixed gas, it is found that the ratio varies from 0.06 to about 15.0. That is, the volume of the water compared to a unit volume of fixed gas varies within wide limits, as it should if surface water, in amounts naturally variable, finds access to the original gases. The smallest quantity of water occurred in samples which were collected close to the only area where extruded lava actually reaches the surface, and where the gases might have been expected to be least affected by surface influences. It was also found that, as a rule, the largest quantity of water occurred in fumaroles which, from the topography, seemed most likely to have been affected by surface water.

A calculation of the amount of water flowing at a given time into the drainage basin in which these fumaroles occurred, and a comparison with that flowing out of it at the same time, proved that the inflow was in large excess. The observations also indicated that this excess must be evaporated chiefly about the fuma-

[12] " Montagne Pelée et ses Eruptions," Paris, 1904, p. 390.

[13] Allen and Zies, unpublished.

[14] Allowance is here made for hydrochloric and hydrofluoric acids which are not included in the *corresponding* analyses at the end of this paper.

roles, and our hypothesis assumes that the steam was drawn through the fumarole walls as others have supposed the atmospheric gases are drawn in. If our findings are correct, the water in the Katmai gases is largely of surface origin, yet even where the gases have presumably been least exposed to surface influences, water is still the preponderating constituent.

The dilution of fumarole gases by steam from surface water has probably always been believed by many geologists, but the evidence for it, so far as we are able to find, is seldom so convincing as it is here.[15]

(a) *The Insignificance of Surface Water in Carrying Down Dissolved Nitrogen.*—Bunsen[16] states that the nitrogen of the Icelandic fumaroles is of atmospheric origin and is carried down in solution by surface water. It is a minor matter, still perhaps worthy of notice, that only a very small fraction of the nitrogen could have been carried down in that way, for a saturated solution of nitrogen in water at $15°$ and the partial pressure of nitrogen in the air would, if volatilized without change in composition, have formed a gas containing only about 0.001 per cent. of nitrogen by volume, whereas the only sufficiently complete analysis of an Icelandic gas, quoted by Bunsen, contained 0.3 per cent. nitrogen and 82.3 per cent. water.[17] The same is true of all recorded analyses of volcanic gases where water and nitrogen are both determined, including the analyses of the Katmai gases; if the water were *all* surface water there would in no case be nearly enough of it to dissolve all the nitrogen. (See Table 2.)

II. The original volcanic gases.

(1) *Summary of Analytic Evidence.*—In the foregoing critique it has been maintained that oxygen in volcanic gases is invariably exotic and that it comes from the air. This implies that at least an equivalent quantity of the inert gases, nitrogen, argon, etc., must have accompanied the oxygen. Evidence has been given which indicates that in some cases the inert gases are wholly or chiefly from atmospheric sources, while in others they

---

[15] See also Brun's statement to the effect that fumarole gases show seasonal variation. " Recherches sur l'Exhalaison Volcanique," Genève, 1911.

[16] Liebig's Ann., **62**, 8, 1847.

[17] Gas from a fumarole at Krisuvik, *Ann. Chim. Phys.*, (3) **38**, 264, 1853.

TABLE II.

Analyses of volcanic gases which include both H_2O and N_2.

Locality	Per cent. H_2O	Per cent. N_2	Authority
Krisuvik, Iceland.............	82.3	0.3	Bunsen[1]
Vesuvius..................	67.74 62.44 72.69 77.76	15.49 24.88 21.23 17.62	Gautier[2]
Kilauea...................	67.99 38.48 17.97 64.71 89.77 64.18 75.08 59.97 89.93 75.09 80.31 84.98 78.71 36.18 50.88 61.56 97.09 67.52 76.84 73.89 66.25 79.31 61.88	23.22 37.84 12.88 10.47 3.50 5.88 0.87 8.92 2.44 7.92 2.37 2.33 20.01 2.41 15.03 4.13 0.68 3.35 2.91 6.20 3.11 1.29 4.50	Shepherd[3]
Mauna Loa..................	75.44 67.43	16.80 15.37	Shepherd[4]
Katmai, Alaska..............	99.97 99.99 99.93 99.96 99.96 99.95 99.90 99.94 99.40 98.60 99.95 99.94 99.96 99.70 99.96	0.017 .003 .018 .015 .018 .024 .024 .009 .049 .179 .006 .002 .004 .268 .004	Allen and Zies[5]

[1] *Ann. chim. phys.*, (3) **38**, 259. 1853.
[2] *Compt. rend.*, **148**, 1708. 1909.
[3] *Bull. Hawaiian Vol. Obs.*, **7**, 94-97, July, 1919; **9**, 86, 1921.
[4] *Bull. Hawaiian Vol. Obs.*, **8**, 65-67, May, 1920.
[5] Unpublished.

are either of deep-seated origin or they possibly have been changed by selective solubility [18] in the magma.

Carbon dioxide, ammonia, and the sulphur gases, while they may find occasional access to the conduits of volcanic gases from outside sources, are of too general occurrence for us to connect them invariably with comparatively superficial formations, for the local existence of which there is often not the slightest evidence.

A satisfactory superficial source for hydrochloric and hydrofluoric acids has, I believe, never been pointed out. Some indeed would derive the chlorine in volcanic gases from sea-water, because volcanoes so frequently occur near the sea-coast; but the gases of the volcanoes of Iceland and Hawaii are singularly low in it, while the gases of the inland volcanoes of Mexico contain it. Furthermore, there is too little fluorine in sea-water to supply, without great concentration, the amounts found in the Katmai gases. While both hydrochloric and hydrofluoric acid gases are doubtless original, we have seen that their quantities are subject to reduction by chemical reactions with the minerals which constitute the walls of the fumaroles.

In addition to the changes which have been described, fumarole gases emerge from the ground at temperatures probably considerably below that of the magma, whence they come, and are therefore subject to chemical changes resulting from shifts in equilibrium. A similar shift of equilibrium may be expected in the process of collecting the gases, especially where they are very hot unless the chilling is very rapid. Changes of this character, while they may alter the original amounts of the gases considerably, will not affect our conclusions as to their original character unless some constituent is thereby reduced to a negligible quantity.

(2) *Gases in Igneous Rocks.* (a) *Their Nature and Amount.* —The researches of Gautier,[19] Chamberlin,[20] and others have

---

[18] The word is used in a general sense; it is not intended to imply a purely physical process. If nitrogen is absorbed by the magma it is probably through chemical combination.

[19] Gautier, *Compt. rend.,* 132, 61, 189, and 932; 136, 16 (1903).

[20] R. T. Chamberlin, " The Gases in Rocks," Carnegie Inst. of Washington, Publ. No. 106. For a complete resumé of the subject see Clarke, F. W., "Data of Geochemistry," 4th ed., p. 268 (1920). See also Brun, A., " Recherches sur l'Exhalaison Volcanique," Genève, 1911.

shown that all igneous rocks contain gases which they give up when heated in a vacuum. The principal constituents of these gases are water, carbon dioxide and hydrogen, while carbon monoxide, nitrogen, methane and hydrogen sulphide are subsidiary. Ammonia and the halogens, as well as oxygen, are almost entirely wanting.[21]

TABLE III.

*Average volumes of various gases obtained from the igneous rocks per volume of rock; reduced to $0°$ and 1 atmosphere and also to $100°$ and 1 atmosphere. **

Order	Type of Rock	No. of analyses	H_2S	CO_2	CO	CH_4	H_2	N_2	Total at $0°$	Total at $100°$
1	Basic schists	2	0.00	4.06	0.19	0.05	3.44	0.13	7.87	10.75
2	Diabases and basalts	14	.19	3.96	.44	.12	2.54	.11	7.36	10.06
3	Gabbros and diorites	11	.02	2.31	.13	.07	2.09	.11	4.73	6.46
4	Granites and gneisses	19	.00	1.47	.22	.05	1.36	.09	3.19	4.36
5	Andesites	7	.00	1.86	.18	.06	.20	.09	2.39	3.27
6	Syenites	4	.00	.18	.07	.05	.91	.04	1.25	1.71
7	Rhyolites	4	.00	.69	.05	.02	.06	.05	.87	1.19
8	Miscellaneous porphyries	2	.00	.32	.06	.04	.33	.04	.79	1.08

* R. T. Chamberlain: "Gases in Rocks," p. 27, Table 13.

TABLE IV.

Average composition of the gases in igneous rocks. Calculated from Table 3 into volume percentages.

Order	Type of Rock	No. of analyses	H_2S	CO_2	CO	CH_4	H_2	N_2	Total
1	Basic schists	2	0.0	51.6	2.4	0.6	43.7	1.7	100%
2	Diabases and basalts	14	2.6	53.8	6.0	1.6	34.5	1.5	100%
3	Gabbros and diorites	11	0.4	48.8	2.7	1.5	44.2	2.4	100%
4	Granites and gneisses.....	19	0.0	46.0	6.9	1.6	42.6	2.9	100%
5	Andesites	7	0.0	77.8	7.5	2.5	8.4	3.8	100%
6	Syenites	4	0.0	14.4	5.6	4.0	72.8	3.2	100%
7	Rhyolites	4	0.0	79.3	5.7	2.3	6.9	5.8	100%
8	Miscellaneous porphyries..	2	0.0	40.5	7.6	5.1	41.8	5.0	100%

The analyses of volcanic gases agree with these results in large measure but not entirely. Nitrogen is generally more abundant in the volcanic gases than in the rocks, a fact which is explained by the atmospheric contamination of the former. The presence of oxygen in the volcanic gases is, as we have seen, similarly accounted for. Hydrogen averages much higher in the rocks—a fact which will be considered later. (See Tables 3 and 4.)

---

[21] Brun claims to find free chlorine, hydrochloric acid and ammonium chloride in comparatively large quantities in some of these gases, *loc. cit.*

Of the water in the igneous rocks Chamberlain makes very little. He apparently doubts its significance and does not include it in his gas analyses. Gautier is impressed with its importance in volcanology, whatever its origin, and he gives the average quantities of water found by him in several classes of rocks. We will not cite his figures here because the rocks taken for his water determinations were obviously not selected in such a way as to serve our present purpose, which is to determine what relation the water holds to the rocks and to the magmas from which the rocks were formed.

Table 5 contains the average percentages of water "above 100°" in the principal types of igneous rocks as computed by

TABLE V.
Average percentage of H_2O+ in igneous rocks.

Type of Rock		Washington[1]		Daly[2]		
		Number of analyses	Per cent. H_2O	Number of analyses	Per cent. H_2O	cent. SiO_2
1	Granite..............	381	0.64	236	0.78	69.73
	Rhyolite.............	181	1.54	64	1.52	72.60
2	Syenite..............	105	0.70	50	0.76	61.99
	Trachyte............	97	1.01	48	1.26	60.68
3	Nephelite syenite.....	72	1.38	43	1.35	54.63
	Phonolite............	76	1.71	25	2.04	57.45
4	Diorite..............	165	0.99	89	1.37	58.38
	Andesite.............	192	1.17	87	1.26	59.59
5	Gabbro..............	150	1.01	41	1.45	48.24
	Basalt	198	1.66	161	1.76	48.78

[1] H. S. Washington, data from Prof. Paper 99; U. S. Geol. Survey.
[2] R. A. Daly, from *Proc. Am. Acad. Arts. Sci.*, XLV, 211, 1910.

Washington and by Daly. The classification into five groups is seen to follow composition, from the most to the least siliceous. Each group is subdivided into plutonic rocks (first given) and effusives. In the main the results of the two authors are in satisfactory agreement. The results of Doctor Washington, which he kindly computed for the writer from his well-known "Analyses of Igneous Rocks," [22] have several claims to first consideration, for: (1) They represent determinations on *rocks entirely free from alteration,* and (2) each average was made from a large number of individual determinations. (3) The rocks to which the water determinations appertain were so selected that plutonic and effusive rocks of the same group are closely comparable in composition. This fact will be later applied to another subject.

[22] Prof. Paper, *U. S. Geol. Survey* No. 99.

If we take 2.65 as the average specific gravity of the granites and 3.00 as the average specific gravity of the basalts, we calculate that the water in the average granite, if entirely expelled at 100° and one atmosphere pressure would occupy a volume thirty times that of the rock, while the water in the average basalt under similar conditions would amount to eighty-seven times the volume of the rock from which it was expelled. A reference to Table 3 shows that these figures far surpass the average volume of all other gases in igneous rocks put together.

The general occurrence of water in the igneous rocks and its high average quantity compared to the other volatile constituents is an indisputable fact, but its significance is not universally accepted.

(b) *The State in Which the Gases are Held in the Rocks.*— Microscopic investigations show that very little of the gases (including water) in rocks can be contained in cavities. Some is probably held in minute cracks which form the boundary planes between the constituent minerals, but the major part is evidently distributed through the minerals themselves and, unless we are content to speculate in the hazy realm of the submicroscopic, the logical conclusion is that they are held by molecular forces. Reverting especially to the water, we know that there are primary minerals, particularly the micas in which all would probably agree that the water is chemically combined. In other minerals where the water bears no simple stoichiometrical relation to the chemical formula there has been a tendency to ignore it, though some include it in more complicated formulæ. This can be done in the case of water with some show of reason, but no one has ever attempted to make hydrogen [23] or carbon dioxide a part of the formula, except in some special case like cancrinite. Whatever may be the exact molecular relationship of water and other gases to the rock, it is a simple conception in good accord with known facts to suppose that a complex solution like a rock magma should, in the act of crystallizing, retain in its constituent minerals some portion of its volatile as well as its non-volatile components, the quantity in each mineral varying according to the composition of the magma, the chemical nature of the mineral and the temperature and pressure to which it is subjected.

(c) *Is Water or Hydrogen the Original Gas?*—Travers and

[23] This of course means hydrogen other than the hydrogen belonging to water.

Gautier have regarded the gases expelled by heat from rocks as not all present originally, but as products of chemical reaction between water and certain minerals in the rock. It is an interesting problem in itself to determine the molecular state of the various gases in the rock, but this will not affect our conclusions regarding the origin of the volcanic gases; we must simply recognize that the relative quantities of certain gases will depend on the temperature at which they are expelled from the rock and upon the extent to which equilibrium between the rock and the gas is attained. For example, Gautier regarded the hydrogen expelled from rocks as a reaction product between water and the ferrous compounds present. We may assume for the sake of simplicity that the reaction is represented by the following equation: $3FeO + H_2O \quad Fe_3O_4 + H_2$, though the ferrous oxide, as a matter of fact, is always *combined*, generally in some more or less complex silicate. However this may be, the reaction between ferrous iron and water in a rock is apparently a reversible one; and if so, any rock which contains these components, as most rocks do, will give off a mixture of hydrogen and water when it is heated and the quantities will depend, as first stated, on whether equilibrium is reached and upon the temperature at which the gases are expelled. The same thing is true of a *magma,* and if we assume either water or hydrogen to have been originally present in the ferriferous igneous rocks, solid or liquid, *the other must be original in the same sense.*

(d) *Which is the Preponderant Gas, Water or Hydrogen?*— In any rock which contains ferrous and ferric iron, in sufficient amount as compared to the water, so that both remain present when the rock is heated, we can not, strictly speaking, define the percentage of water unless we refer to some definite temperature; and an exact determination of the water can only be made by keeping the expelled gases in contact with the rock powder at the constant temperature specified until equilibrium is reached, before the gases are removed and analyzed. No investigator has followed such conditions.

How far, then, can we make any statement regarding the relative amounts of water and hydrogen in a particular rock or in the magma whence the rock originated, defining *amount* in terms of the volume which the two substances would occupy in the gaseous state? We have already seen that the "volume" of water

actually found in rocks is, on the average, in great excess over hydrogen. Now although the determinations are admittedly inexact, it is safe to say that water is in fact predominant as a rule, if not in all rocks, at all temperatures below melting. If the determinations were not approximately correct it would be impossible in the analysis of many rocks to get an acceptable summation, for the disparity in weight between water and its equivalent of hydrogen is very large and the determination of ferrous iron is quite independent of the water determination so that there could be no compensation between the two. Where low percentages of water are found the error might not be detected, but in rocks found to be high in both water and ferrous iron it would be impossible to mistake a preponderant volume of water for a preponderant volume of hydrogen.

Again, the *water content is often considerable in rocks and minerals which are almost free from iron.* Washington lists a pitchstone [24] from New South Wales containing 10.5 per cent. of water by weight and only 0.21 per cent. of ferrous oxide. Assuming 2.25 as the specific gravity of the rock, the water as vapor at 100° and one atmosphere pressure would amount to over 400 volumes per volume of rock. While the hydrogen was not determined, it is safe to say its volume must have been insignificant in comparison, for the hydrogen equivalent to the full amount of ferrous oxide would be very small, and, moreover, Chamberlin's analyses include no igneous rock of any description which contains more than a few per cent. of the above volume. The preponderant water in this rock must therefore have been originally present as such, or at least in a form which would give up water on heating. In the case of this rock, we may safely go farther. Since hygroscopic water (included in the 10.5 per cent.) in rocks of this character is insignificant, and since the rock showed no sign of alteration, we may infer that most of this water was contained in the original magma. This case is selected as an example; no doubt many rocks low in iron and high in water could be found which would confirm the above evidence.

We conclude, then, that while the water determinations in ferriferous minerals and rocks are *not exact,* they are in general

---

[24] Prof. Paper, *U. S. Geol. Survey,* No. 99, p. 103.

close enough to warrant the statement that the volume [25] of water (as vapor) in the rocks is preponderant over hydrogen.

Does the same conclusion hold good for the magma? Analyses of the volcanic gases show that in the great majority of cases water is greatly preponderant over hydrogen, but it is possible that the gases may have undergone some change after leaving the magma. Jaggar believes that hydrogen is much greater in amount in the *original* volcanic gases than it is in gases which have so far been collected. It is his view that the original hydrogen has suffered partial oxidation on approaching the surface. At Kilauea there is good evidence for surface oxidation, but before accepting Jaggar's view respecting the preponderance of original hydrogen it ought to be noted first that he has no evidence bearing on the *amount* of oxidation. Shepherd [26] makes the following statement on this point, based on the study of the Kilauea gases: " The quantity of water found (in the gases) is much too great to be accounted for on the direct air oxidation hypothesis and the main question answered in 1912—that is as to the supposed ' anhydricity ' of the gases has been entirely settled. At Kilauea the major constituent of the gas is water and the question as to its meteoric or plutonic origin has now been fairly well established in favor of the plutonic."

As to volcanic gases in general, it has not been shown that the conditions at Kilauea are characteristic of other volcanic craters. The saucer-like basin in which the lava is peculiarly exposed to the air at all times when gases can be collected and the downward transport of air by floating crust and infalling talus are, so far as known, unique.

When gases arise from lava which stands at a level well below the surface of the ground, and issue in large volumes from narrow funnels, oxidation like that at Kilauea ought to be practically obviated. In volcanoes of this character satisfactory evidence as to oxidation of the gases can only be obtained from such as issue from fumaroles. Although it has been so far impossible to determine how much of the water in such gases is original, some of them contain in the fixed portion more combustible gas than the Kilauea gases do in spite of the fact that fumarole gases as a rule have

---

[25] It will be understood here that the comparison of volumes presupposes expulsion of the gases from the rock.

[21] *Bull. Hawaiian Volcano Obs.*, **9**, 86. 1921.

probably suffered some oxidation. This is generally true of the Katmai gases.

So, while surface oxidation of original volcanic gases may be important in some places, and while various degrees of oxidation probably occur in fumaroles, Jaggar's evidence even at Kilauea itself is by no means sufficient to prove that hydrogen is more important than water in the original volcanic gases. Besides oxidation, however, volcanic gases may undergo other changes after leaving the magma. The simplest is dilution by air or by water vapor. We have shown the probability of this change already. In particular cases this influence might disguise the original character of the gases, but at Katmai, where the gases were collected with particular pains to exclude air, the evidence indicated that the original gases were highly aqueous.

Still another change which volcanic gases may undergo after leaving the magma, already alluded to in a general way, is a shift in equilibrium which obviously has a bearing on the question in hand. The total number of constituents of importance in a volcanic gas is fortunately small, and we can predict with some confidence the principal reactions which apply here. They are:

(1) $CO_2 + H_2 \rightleftarrows H_2O + CO$.
(2) $3S_2 + 4H_2O \rightleftarrows 4H_2S + 2SO_2$.
(3) $H_2S + 2H_2O \rightleftarrows 3H_2 + SO_2$.
(4) $2H_2S \rightleftarrows 2H_2 + S_2$.

In the first reaction—the water gas reaction—a rise in temperature results in an increase in the water; in (2) and (3) the same change results in a decrease in water, while in (3) and (4) the concentration of hydrogen increases.[27]

It would be difficult to calculate what the final result would be in a case of such complexity even if we had the data; the change in the concentration of water and hydrogen with rising temperature would depend on the quantities of the water, the carbon dioxide, and the sulphur gases; but it will be noted that any change in these concentrations which could alter our conclusion regarding the preponderance of water would have to be brought about by the sulphur gases, and we shall find later evidence which indicates that these are usually minor constituents of the magma. This conclusion depends on the assumption that water is preponderant at low temperatures, as it generally is in the rocks,

---

[27] For the heat effects which govern these reactions see p. 32.

and on the assumption that carbon monoxide is insignificant in comparison.[28]

Some speculation which is pertinent to this question has been done by Daly and by Chamberlin [29] on the reaction represented by the equation
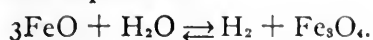
$$3FeO + H_2O \rightleftarrows H_2 + Fe_3O_4.$$
$$192900 \text{ cal} + 59880 \text{ cal} = 264900 \text{ cal} - 12120 \text{ cal}\ [30].$$

It has been noted that in accordance with the heat absorption this reaction should proceed from right to left as the temperature rises; consequently the concentration of water vapor in the gases should increase. The same reasoning has been applied to the reaction which takes place between the water and the ferrous minerals in a rock powder, but our knowledge of these reactions is quite imperfect. The original ferrous silicates—olivine, hypersthene, hornblende, diallage—are easily identified and the evidence of Gautier and Chamberlin indicates a reversible reaction involving either these silicates directly or possibly ferrous oxide forming from them in a preliminary reaction. Gautier states that the action of water on the ferrous silicates produces magnetite or ferric silicate.

As a matter of fact we do not know the products and we are not quite sure that the reaction is reversible. Recently Ferguson,[31] in a series of experiments performed in this Laboratory, was unable to find that steam has any action on the lava from Kilauea, which is quite rich in ferrous silicate, even at 1100°.

If the reaction is really reversible and the *sign of the heat change* is the same in the rock powder and in the magma as it is in the simpler process which we have discussed, the magmatic gases should be richer in water vapor than the gases which are expelled by heat from rocks, and we have already seen that in the latter the volume of water vapor exceeds on the average the volume of all the other gases combined.

Gautier [32] holds interesting views on the relations of water and hydrogen in the magma, but they are not altogether clear.

---

[28] Like all other constituents in volcanic gases CO is variable, but usually its concentration is low and probably always low compared to water.

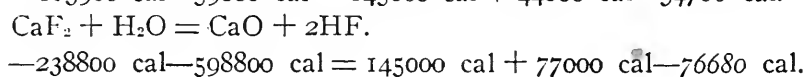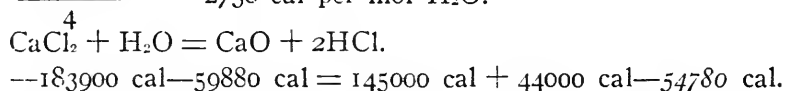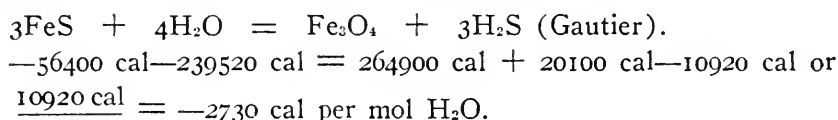[29] R. A. Daly, *op. cit.,* p. 86; R. T. Chamberlin, *op. cit.,* p. 41.

[30] The heats of formation from the elements.

[31] *Jour. Wash. Acad. Sci.,* 9, 539, 1920.

[32] *Ann. des Mines* (10), 9, 344, 368, 1906.

While he believes that water is present in the magma, he apparently regards it as a reduction product of the magmatic oxides by hydrogen which is continuously emanating from the depths of the globe. Hydrogen in the magma as well as in the rocks is (he believes) also liberated by the reaction of water with ferrous minerals. If he accepts the reversibility of the reactions, his statements imply that the ratio of water vapor to hydrogen *decreases* as the temperature rises. This view may be legitimate in view of the conflicting evidence, but a *discontinuous* change from water in the magma to hydrogen in the depths of the globe is out of accord with chemical principle.[33]

(e) *Other Chemical Reactions Between Water and Minerals.* —Water reacts with the sulphides and halides (if present) in the rocks, when they are heated, with the formation of hydrogen sulphide (and its decomposition products) and the halogen acids; but very small quantities of hydrogen sulphide are actually obtained from rocks by this process and the halogen acids have not been detected at all in analyses of the gases.[34] Nevertheless these gases are a characteristic part of the emanation from many volcanic craters, and the chemical properties of the gases and of lavas justify us in assuming that the former are products of the reaction of water on sulphide and halide molecules dissolved in the magma. These sulphides and halides are all decomposed by water with absorption of heat, as the following typical equations show:

$3FeS + 4H_2O = Fe_3O_4 + 3H_2S$ (Gautier).
—56400 cal—239520 cal $=$ 264900 cal $+$ 20100 cal—10920 cal or
$\frac{10920 \text{ cal}}{4} = $ —2730 cal per mol H_2O.
$CaCl_2 + H_2O = CaO + 2HCl$.
—183900 cal—59880 cal $=$ 145000 cal $+$ 44000 cal—54780 cal.
$CaF_2 + H_2O = CaO + 2HF$.
—238800 cal—598800 cal $=$ 145000 cal $+$ 77000 cal—76680 cal.

As in a previous case, we must be cautious about applying these equations *to the magma* where the heats of solution by the magma of all the different substances enter into the result. But heats of solution are as a rule much lower than heats of formation from

[33] This statement is not to be understood as a denial of the gradual dissociation of water in the magma at *very high* temperatures.

[34] Except by Brun.

the elements.[35]   In the case of the second and third equations,
at any rate, the heat effect is so large that a change in its sign
by solution of all the substances in the magma appears quite im-
probable.   Assuming the correctness of our inferences, there
should be more of the halogen acids in the magma and in the
vapor phase at *high* temperatures in accordance with the heat
absorption and the higher vapor pressure.   In other words, the
maximum concentration of these gases in the volcanic exhalations
should be found when the eruption is at a climax.   This may also
be true of hydrogen sulphide and its dissociation products, though
the case is not so clear as it is for the halogens, for the heat in the
reaction as represented is comparatively small and may change in
sign when it goes on in the magma.

This reasoning depends on a previous conclusion (pp. 14 and
16) which should be kept constantly in mind, *viz.*, that the volume
of water dissolved in the magma is, as a rule, greatly in excess of
the volume of all other gases.   Water is involved in a number of
chemical reactions which doubtless take place in the magma; con-
sequently the mass of it in a unit volume of magma is subject to
variation *from several sources,* as the temperature changes.   If the
mass of water therefore were sufficiently small the conclusion
respecting the concentration of halogen acid (and hydrogen sul-
phide) in the volcanic gases would no longer hold good.   These
statements apply to the original gases.   We have seen that the latter
may be further modified when they issue from fumaroles.

The inference respecting the amounts of the halogen acids
in volcanic gases is not entirely borne out by field evidence.
Deville and others state that the emanations from certain incandes-
cent lavas are chiefly *sodium chloride,* while *hydrogen chloride* is
obtained when the eruption has waned somewhat, or in a less
active part of the field at the same time.   This may possibly mean
that certain lavas are low in water, as Deville [36] affirmed, though
the evidence *in general* is decidedly against this claim.

(f) *Reactions Between Certain Gases.*—We have so far con-
sidered those volcanic gases which result from interaction between
water and certain constituents of the rocks though both the water

---

[35] The heat effect of changing CaO to $CaSiO_3$ and liquefying the same
is about 48000 cal compared to 145000 cal (Moissan) for the heat of formation
of CaO.   The heats of "solution" of $CaCl_2$, HCl and H_2O are probably high,
but much lower than their heats of formation.

[36] Deville and Leblanc: *Bull. Soc. Geol.,* France (2), 13, 606, 1855-6.

and the product are to be regarded as original. It should also be noted that the coexistence of certain gases necessarily gives rise to others. Thus carbon monoxide is known to be a reduction product of carbon dioxide by hydrogen. $CO_2 + H_2 \rightleftarrows CO + H_2O$. Further reduction of carbon monoxide by hydrogen with the formation of marsh gas appears to be an accomplished fact, though its formation at *high temperature* as claimed by Gautier is in ill accord with almost complete thermal dissociation at 800° asserted by others.[37]

The oxidation of sulphur vapor by carbon dioxide: $S_2 + 4CO_2 \rightleftarrows 2SO_2 + 4CO$ has been carefully investigated by Ferguson.[38]

Ferguson's results show that below 900° the reduction of carbon dioxide by sulphur vapor is unimportant. They also permit us to calculate, where the composition of the gas is known at any temperature, the shift in equilibrium over any temperature interval.

Another gas reaction which would seem altogether probable in the magma is that between sulphur and water: $3S_2 + 4H_2O \rightleftarrows 4H_2S + 2SO_2$, for though the products of the reaction are incompatible at low temperatures they are not so at high temperatures.

Still another reaction equally probable is: $3H_2 + SO_2 \rightleftarrows 2H_2O + H_2S$.

Since these reactions are all well known, we may see from a glance at the equations that any primary volcanic gas which contains the common constituents water, carbon dioxide and carbon monoxide and at the same time any one of the sulphur gases must contain all the rest. It is, however, certain that SO_2 would often be entirely decomposed by excess of H_2S before it reached the collecting tube. The field conditions brought out in our critique have shown that some oxidation of combustible gases is likely to occur before the collecting point is reached, and since sulphur and sulphur dioxide are both oxidation products of hydrogen sulphide, both may be secondary gases.

All these reactions have necessarily been considered one by one, but it will be evident that they are closely related as parts of the same complex system consisting of the magma alone or embracing the gas phase above it when there is one. In this system of course the molecular forces are all striving toward a chemical equilibrium

[37] See Abegg's " Handbuch der anorg. Chem.," iii, p. 73, Leipzig, 1909.

[38] *Journ. Am. Chem. Soc.,* **40**, 1626, 1918.

—an equilibrium which, however, may never be reached because of opposing forces.

(3) *The Origin of Sulphur, Chlorine and Fluorine in the Volcanic Gases.*—The quantities of sulphur (as H_2S, SO_2 and free sulphur), as well as chlorine and fluorine which occur in volcanic gases, lead us to the magma as their probable source. If they occur there, a residual portion should still exist in the igneous rocks along with hydrogen, carbon dioxide, etc. Investigators in this field have evidently not recovered the halogens and only a very little sulphur by heating rock powder in a vacuum (see p. 12). Perhaps their failure is accounted for by experimental difficulties, as small quantities of these elements occur in igneous rocks. At first sight the amounts seem insignificant, but calculation proves that the *volumes* are comparable with those of the other gases with the exception of water, carbon dioxide and hydrogen. If we accept the average weight pecentages of sulphur, chlorine and fluorine [39] as 0.08 per cent., 0.096 per cent. and 0.04 per cent., respectively, and if we assume that all three are converted by the action of water entirely into H_2S, HCl and HF, the volumes of the gases at 0° and one atmosphere pressure would amount to 1.5, 1.7 and 1.3 volumes per volume of rock. (Compare Table 3.)

When volcanic activity takes the eruptive form a large portion of the sulphur and halogens are lost to the air with other volcanic gases, but a portion is fixed in the walls of the fumaroles or forms incrustations on the ground about the vents. Among the fumarole products at Katmai are found zinc, copper, and molybdenum [40] in amounts which are large compared to those found in the ash on which the incrustations occur. Whether these metals as halides were driven out of the magma along with the more generally recognized volcanic gases is not yet known, but it may well be. Interesting possibilities suggest themselves regarding the extent to which halides like those of the metals in question can be carried along by a gas consisting largely of steam which must tend to hydrolyze the halides and precipitate the oxides of the metals— by a gas containing also sulphur or sulphide of hydrogen which tends to precipitate the metals as sulphides. How great a partial pressure of the halogen acids compared to those of the

[39] Clarke and Washington, unpublished work.

[40] Work on the incrustations of the Katmai fumarolic area is in progress and will be published in a forthcoming paper by E. G. Zies.

steam and hydrogen sulphide would be required to prevent precipitation of these metals from the gaseous state is a problem for the chemist.

When volcanic activity assumes the *intrusive* form geologic investigation reveals very commonly a segregation of the sulphur and fluorine of the magma, together with various metals which form volatile halides, in the form of veins. The whole process is still obscure. To what extent a preliminary volatilization occurs is not known, but there seems to be no obvious relation between the volatility of the halides of the metals and the order of deposition of the metals in the veins. The order suggests crystallization from solutions, which leads to the inference that the final process in filling of the veins was accomplished through the agency of hot waters derived by condensation from magmatic gases but augmented no doubt by ground water.

(4) *The Ultimate Origin of the Volcanic Gases.*—Thus nearly all the volcanic gases are traced directly to the igneous rocks, and the evidence is strong that they formed a part of the magmatic solution from which the rocks crystallized. We shall not attempt to trace them further. Those who adhere to the planetesimal hypothesis may find comfort in the fact that meteorites contain similar gases, and that the meteorites may therefore be the ultimate origin, but it seems equally plausible that these elements form a part of the cosmic material of which all the heavenly bodies are composed.

From numerous eruptive vents the volcanic gases are pouring forth, and have been pouring into our atmosphere since the beginning of time. What becomes of them? Do they disappear in various natural processes like the oxidation of the combustible gases and the absorption of carbon dioxide by plants; are they swallowed up by the vast volume of the air in which their amounts are entirely negligible, or is our atmosphere very slowly changing?

Gautier [41] sees in the eruptive process, especially in the milder form which according to him involves the *distillation* of water and other gases from the rocks, giving rise to the hot springs, one phase of a vast system of circulation, the other of which returns the water and atmospheric gases to the rocks which have lost them. The geological effects of water, oxygen and carbon dioxide in the surface strata of the earth are of course universally recognized,

[41] *Ann. des Mines* (10), **9,** 269, 1906.

but " gravity, capillarity and chemical action " do not appear to me competent to return the volcanic gases to their original source. The theory seems chimerical in spite of the attractiveness of its element of natural economy.

III. DEVILLE'S GENERALIZATIONS RESPECTING THE VOLCANIC GASES.

I. Statement and interpretation of the generalizations.

About seventy years ago Deville,[42] as a result of extensive investigations, formulated a number of interesting generalizations which correlated the composition of volcanic gases with the progressive stages of a volcanic eruption.   He maintained: (I) That the composition of the volcanic gases passes through a number of distinct stages as one proceeds outward from an eruptive centre. Thus from incandescent lavas the exhalation is principally anhydrous vapor of sodium chloride.   In the next stage the gases consist of steam, hydrochloric acid, and sulphur dioxide.   In a third stage carbon dioxide is dominant, and finally water vapor alone.   (2) That as an eruption dies out, the different stages succeed one another at a given point in the same order.   (3) That the same changes follow one another in the same order all over the globe.

Fouqué later corrected Deville's statement regarding the generally anhydrous nature of the gases from incandescent lava, but with more or less modification these generalizations seem to have been commonly accepted by volcanologists.   The generalizations imply that the original gases are the same all over the globe and that their subsequent variations are due entirely or chiefly to temperature changes, or that if any other agency has been active it is everywhere equally potent.   This is obviously not the same thing as saying that a gas mixture possesses a different equilibrium for every temperature; the gases in certain of Deville's stages contain elements which were not present in the beginning in any form whatever.   The generalizations rather suggest that the gaseous mixtures form a part of more complex and variable heterogeneous systems and that their composition is a result not only of reactions among themselves but with other substances,

---

[42] Deville and Leblanc: *Bull. Soc. Geol.,* France, 2nd Series, 13, p. 606 (1855-6) ; 14, p. 254 (1856-7).   See also F. von Wolff: "Vulcanismus Stuttgart," 1914, p. 563.

notably the constituents of the magma from which they emanated.

II. The actual relations existing between temperature and the composition of volcanic gases.

One of the main objectives in the investigation of the Katmai fumaroles was to find whether there was any relation between the composition of the gases and the temperature at which they issued from the ground. Careful temperature measurements were therefore made in all the vents from which gases were taken. The temperatures varied from 100° to 440°. There was considerable variation in the composition of the gases, but it was impossible to discover any systematic variation in respect to any constituent except the acid gases, hydrochloric and hydrofluoric acids, the concentration of which was obviously dependent on temperature. The marsh gas varied from practically nothing to over 10 per cent. but, so far as our investigation went, the variation was of a purely local character; the gases containing the larger percentages were all confined to a single small basin.

Having satisfied ourselves that the variations in the composition of the Katmai gases were not due chiefly to temperature differences, we made a survey of the whole literature of the subject. It is not surprising to find that temperature data are commonly wanting, but a consideration of the available data showed no such systematic variation as Deville's generalizations imply. Wolff [43] in his book on volcanology comes to a similar conclusion, except that he regards the vapors of sodium chloride as characteristic of incandescent lavas. But even this is not general; in Hawaii [44] and in Iceland scarcely any chlorine has been found in the exhalations. Chlorine seems not to be a component of all magmas and apparently fluorine is insignificant in some. Nor is there any reason to suppose that there should be uniformity respecting the volatile components of a magma while there is certainly none respecting the non-volatile components. When we come to consider the presence of gases *containing the same elements*, H_2, H_2O; CO_2, CO and CH_4; S, H_2S, SO_2, we have seen that the question is not simply one of equilibrium between the gases themselves escaping from an indifferent solvent; the non-volatile portions also enter into the system. Iron in the magma

---

[43] Vulkanismus. Bd. i, p. 580.

[44] Brun's evidence conflicts with this statement.

directly conditions the relative quantities of H_2O and H_2, and the quantity of iron varies in different lavas even from the same crater.

Equilibrium between the gases and the magma may or may not be attained. Explosive processes are proverbially unfavorable to equilibrium so that eruptions of the explosive type might be expected to cause variations in the gases for this reason alone. Nor do disturbing conditions cease with the release of gases from the magma. If the gases find their way to the surface through fumaroles, they are liable, as we have already found, to lose some of their constituents by reaction with the minerals in the walls of the fumaroles, or to gain others in various ways. In view of all the disturbing influences uniformity could hardly be expected. A certain degree of it may exist in particular localities, but such a degree of regularity as Deville imagined certainly does not exist.

IV. THE MAGMA CHEMICALLY CONSIDERED.

I. The complexity of the process of solution of gases.

We have seen that the solution of many of the gases in a magma must be a highly complex process. The solution of water, for instance, probably results in the formation of many oxide molecules by interactions with ferrous oxide and with sulphides and halides in the melt. At the same time other molecules like hydrogen, hydrogen sulphide and the halogen acids are liberated. Some of the water may also form hydrate molecules, while the displacement of silica by water at high temperatures, according to Arrhenius' hypothesis may also be a possibility. If we regard the solution of hydrogen sulphide or a halogen acid by itself, it is highly probable, as we have seen, that a portion would dissolve with the formation of water and of sulphide or halide molecules. This we may legitimately infer from the minerals which are found in the rocks and from general chemical knowledge.

Molecular forces in the magma are tending to bring the whole mass toward homogeneity and chemical equilibrium, but they may be thwarted by other forces. It might as well be conceded at once that *an actual magma in a state of equilibrium is unthinkable;* the temperature gradient of the globe would prove an insurmountable obstacle to thermal uniformity and consequently to chemical equilibrium. This statement would hold good even if the globe, according to an old theory, were a molten mass beneath

a solid crust : the upper strata would still be cooler than the lower. So much the more would the statement be true if volcanic activity were decidedly localized and the magma were limited by colder material like a mass of hot glass in a pot. This would apply especially to great masses of magma, but it might seem possible that comparatively small masses should show approximate homogeneity. The long series of careful observations that have been made at Kilauea by Green, Jaggar, Day and Shepherd, Daly and others, prove conclusively that the magma there is very far from homogeneity; there are pools or wells of hotter and thinner liquid supported at various levels by a stiff viscous paste—which is circulating by convection in the crater and the gases differ in volume and composition at different points and at different times. In this highly fusible lava stirred by comparatively effective circulation one would suppose, if anywhere in a natural magma, homogeneity might be found. The reality is quite otherwise.

Obviously, then, we must proceed cautiously in the attempt to apply laboratory generalizations to rock magmas. Yet I believe it is possible, using the equilibrium state as a limiting case, to apply certain principles which may help to clear up a little of the confusion which sometimes manifests itself in the literature of the subject.

II. The laws which are supposed to apply to the magma.

In the first place there is no reason to believe that the magma is an exceptional liquid in its behavior respecting the solution of gases; the process should be attended with a positive heat effect as it is with all other liquids, and it should respond to pressure and temperature in the same way.

For example, the solution of a gas in a magma ought to increase with pressure as it does for all similar cases. As a result gas bubbles would be expected to disappear entirely at the enormous pressure in the greath depths of the earth. Failure to recognize this appears to be a fatal defect in Daly's two-phase convection theory when applied, as it is by him, to depths of tens of miles.[45]

This objection has already been noted by others.[46] There is also no known reason why the solubility of gases in a magma

[45] Proc. Am. Acad. Arts Sci., 47, 47, 1911.

[46] Day and Shepherd: Bull. Geol. Soc. Amer., 24, 573, 1913; Jaggar: Bull. Seis. Soc. Amer., 10, 168, 1920.

should not increase with falling temperature so long as the magma remains liquid. There is, however, evidence which indicates that magmas may give up gas abruptly in the process of crystallization. It is a fact of common observation in this Laboratory that silicate melts give out a visible amount of gas when they crystallize. I once saw a melt of this kind froth over at the moment of crystallization, forming a vesicular mass. Other facts of an apparently analogous character are known. Perhaps the most pertinent is the release by molten silver of dissolved oxygen at the moment of freezing. These facts appear to mean that gas may have a much higher solubility in a liquid phase than it does in the solid at the same temperature. The conclusion is confirmed in respect to the solubility of *water vapor* in magmas, by the analyses of rocks.[47]

Reference to Table 5 shows that the several classes of effusive rocks all average higher in water than the plutonic rocks of comparable composition. Now the latter are completely crystalline, while the former are nearly always more or less glassy—some of them completely glassy; that is, in a thermal sense they are still partially or wholly liquid. Of course there is great variation in the amount of water that individual effusive rocks contain. The variation is due no doubt to original differences in different magmas and to the diversity of physical conditions which they have passed through—more especially in their rate of cooling. Nevertheless the basalts in general contain more water the more glassy they are, and the very highest percentages of water occur in the pitchstones which are entirely glassy.

These facts indicate that magmas give up a notable percentage of their water in the act of crystallizing.

It should be admitted in this connection that the pumices which are a characteristic product of explosive activity are chiefly glassy, though it may be possible, as Daly [48] believes, that a crystallization of the cooler portion of the magma next the walls of a sealed crater can result in an evolution of gas sufficient to cause explosion while the great mass of the magma is still liquid.

We have pictured the magma as a two-phase system to assist in explaining what changes may go on in the solution or evolution of gases. How the composition of escaping gases is probably

---

[47] H. S. Washington :. "Analyses of Igneous Rocks," *U. S. Geol. Survey. Prof. Paper* No. 99.

[48] *Proc. Am. Acad. Arts Sci.*, **47**, 47, 1911.

affected by changing temperature has already been touched upon (see p. 20).

Another condition of the magma which interests the chemist is its existence in single phase where pressure entirely prevents the escape of gases. We will consider this condition presently (see V, 2).
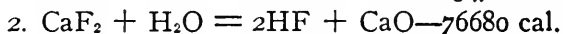
V. CHEMICAL ENERGY IN VOLCANIC ACTION.

I. Heat from the decomposition of endothermic substances.

It has been suggested by Arrhenius [49] that the heat of the sun is kept up by decomposition of endothermic substances. While such substances should theoretically be more stable at high temperatures and ought to decompose and give out heat as they cool, the existence of any such substance in magmas is a mere surmise and too little is known of the practicability of the formation of substances of this nature at high temperatures to give the suggestion much standing.

II. Heat from shifting chemical equilibria of the ordinary sort.

It has also been suggested that a great deal of heat may be derived from shifting chemical equilibria [50] of the ordinary sort in a cooling magma. All reactions which proceed with absorption of heat as the temperature is raised must of necessity give out heat when reversed by cooling. Reactions between the volcanic gases and the magma such as we have already considered, and dissociations of gases or of non-volatile substances in the melt so far as they occur, belong in this class. When it is borne in mind that reactions of this character generally involve heat effects of a much higher order of magnitude than specific heats and ordinary heats of solution, the conception seems worthy of consideration. Let us assume now that the reactions we have been considering proceed in the magma without absorption or escape of gas. The following reactions which have already been discussed involve large quantities of heat; at least this is true when each substance is possessed of its characteristic state of aggregation. We have seen that this may be considerably modified (see p. 20) when the substances are all brought into a magmatic solution.

1. $CaCl_2 + H_2O = 2HCl + CaO—54780$ cal.
2. $CaF_2 + H_2O = 2HF + CaO—76680$ cal.
3. $2NaCl + H_2O = 2HCl + Na_2O—110980$ cal.

[49] "Worlds in the Making," p. 91, (New York, 1918).

[50] Daly: "Nature of Volcanic Action," *Proc. Am. Acad. Arts Sci.*, **47**, 47, 1911. Day and Shepherd: *Bull. Geol. Soc. Amer.*, **24**, 573, 1913.

The following reactions involve only moderate heat changes:

4. $3FeO + H_2O = Fe_3O_4 + H_2 + 12120$ cal.

5. $3FeS + 4H_2O = Fe_3O_4 + 3H_2S - 10920$ cal (2730 cal per mol H_2O).
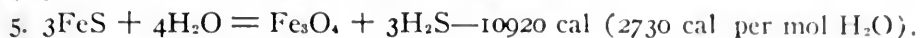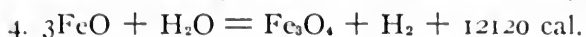
The magnitude of the heat effects which result from these reactions will depend first on the *quantity of the substances involved*. Since the percentage of the halogens *in many magmas* at least must be very limited (judging by the gases they exhale and by the residual quantities in rocks) the possible heat effects from any reactions involving them must be correspondingly small. Furthermore the total heat effect from any reversible reaction must of course depend on the *extent of the shift* which the equilibrium undergoes. To take a concrete example, suppose that a magma containing 10 per cent. of water by weight and no other substance which could react with it is cooled from 1880° to about 1200°. Assume further that the water is dissociated over this temperature interval to the same degree in the magma that it is in a state of vapor, and that the mean specific heat of the lava is 0.3 [51] for the whole temperature interval. We can be sure that the heat effect would be almost entirely determined by the heat capacity of the magma. The degree of dissociation of the water at the higher temperature is so small that, in spite of the great heat of reaction, the recombination of hydrogen and oxygen would give a heat effect less than 2 per cent. of the total. Only in cases where the degree of dissociation permits a wide shift in equilibrium can these recombinations assume an important rôle. Only at temperatures much beyond the measured temperatures of magmas does the dissociation of water, for example, or of carbon dioxide become significant.

The degree of dissociation in hydrogen sulphide [52] is indeed large at 1200°, but sulphur is generally, probably always, a minor constituent of the magma. The total heat effect due to recombination is in this case also dependent on a small heat of formation; if Thomsen's [53] formula—$H_2S = 4435 + 1.9t$ cal—holds for high temperatures, it is only about 6700 cal at 1200°.

---

[51] This value may be too high, but a lava containing so much water would possess an abnormally high specific heat.

[52] Preunner and Schupp: *Zeit. phys. Chem.,* **68**, 161, 1909.

[53] "Thermochemistry," p. 245. Trans. by Burke. (London and New York, 1908.)

A number of gas reactions considered on page 21 involve considerable heat effects. Thus:

$$S_2 + 4CO_2 \rightleftharpoons 4CO + 2SO_2.$$
$$387840 \text{ cal} = 116000 \text{ cal} + 138520 \text{ cal} + 133320 \text{ cal}; \text{ or}$$
$$\frac{133320}{4} \text{ cal} = 33330 \text{ cal per mol of } CO_2.$$
$$3S_2 + 4H_2O \rightleftharpoons 4H_2S + 2SO_2.$$
$$239520 \text{ cal} = 26800 \text{ cal} + 138520 \text{ cal} + 74200 \text{ cal}; \text{ or}$$
$$\frac{74200}{4} \text{ cal} = 18550 \text{ cal per mol of } H_2O.$$
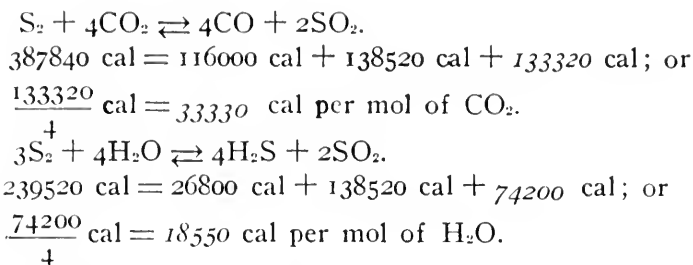
The following reaction is thermally less important:

$$CO_2 + H_2 \rightleftharpoons H_2O + CO.$$
$$96960 \text{ cal} = 59880 \text{ cal} + 29000 \text{ cal} + 8080 \text{ cal}.$$

In making any estimate of the thermal effect of these reactions in a cooling magma, it should be borne in mind that sulphur and the halogens are minor constituents of the igneous rocks and would remain so if they were multiplied many fold. In all probability, therefore, they are minor constituents of the magma, and the thermal effects of reactions in which they take part must be correspondingly limited. Ferrous iron, it is true, reaches much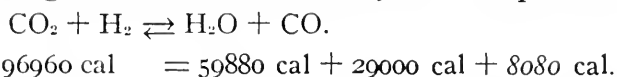 higher values as a magmatic component, and when ferrous iron and water are both relatively high it may be that the reaction between them becomes important. There are magmas, on the other hand, very low in ferrous iron where the heat effect of this reaction must be trifling. On the whole it does not seem probable that very large stores of chemical energy are to be found in the gas reactions of a magma compared with the specific heat of the gas-free lava. It can not be denied, however, that other reactions in the melt, such as the association of hydrates or reactions between the non-volatile substances, may be of significance.

Whether large or small, all such thermal reactions would become effective only in the process of cooling. If they serve as an agency in the depths for heating cooler rocks or magma which contains similar gases in similar concentrations, it is obvious that this chemical energy would be practically balanced against the absorption of heat in the cooler rock; in the heating of a rock which had already lost much of its gas such a magma would be more effective.

The initiation of volcanic phenomena involves, of course, an abnormally high temperature at some locality in the earth's crust, but how this could be originally brought about through chemical

energy it is difficult to imagine. Magmatic intrusion seems to be a necessary preliminary and this demands the intervention of mechanical energy. At the best we seem to be driven to this position: So far as buried magma is concerned chemical energy may have considerable effect in increasing its heat capacity and prolonging the period of intrusive or eruptive activity, but in initiating the activity or in rejuvenating declining activity, it must from the nature of the case be ineffective.

Possibly it may be asked whether some reservation ought not to be made here because of the influence of high pressures on the equilibria in question. It is safe to answer that so long as the magma remains entirely liquid this factor is unimportant. Pressure causes a shift in equilibrium, to be sure, in the direction of diminishing volume, but since the density of the earth as a whole is only about twice the density of the average rock, and since the depth at which intrusion is supposed to take place is less than $\frac{1}{100}$ of the earth's radius, the magnitude of this volume change must be small.

So far we have kept in mind the magma in the *liquid state*. If crystallization [54] takes place the heat effects may be large, though this is not strictly a chemical change, and again it is induced by cooling. It is indeed conceivable that crystallization should be brought about *without cooling*. Suppose that a deep-seated magma entirely liquid were subjected to pressure as a result of contraction in the earth's crust. Crystallization might take place on account of decreased solubility of some mineral or minerals despite the rise in temperature which would inevitably follow compression. In that case a further heat effect would be obtained from the crystallization, but it will be observed here also that the intervention of mechanical energy is essential, so that even if we class crystallization as a chemical action, we need make no reservations respecting pressure in our conclusion regarding the part played by chemical energy in volcanism.

III. Heat from surface oxidation.

When the magma reaches the surface, oxidation of the combustible gases by air may play an important rôle in the volcanic phenomena. We have already seen that the extent of such oxida-

[54] For the latent heat of silicates see O. Mulert: *Z. anorg. Chem.*, 75, 198, 1912; W. P. White: *Z. anorg. Chem.*, 69, 348, 1911: *Am. Jour. Sci.*, 28, 486, 1909.

tion necessarily depends on conditions at the crater. At Kilauea oxidation by the air appears to contribute a considerable amount of heat to the magma.

In 1912 Day and Shepherd [55] made the important observation that " when the gases given off by the lava increase in quantity, the quantity of the lava (lava-level in the basin) remaining the same, the temperature *increases,* and, conversely, when less gas is discharged through the lava, this temperature *diminishes again."* At the same time these authors found that " successive tubes (of gas) collected from the volcano at the same time do not show the individual gases to be present in the same proportions, but rather in proportions which change with every bubble which bursts from the liquid basin." In consequence of these observations they concluded that the lava was heated by a store of energy in the gases which were probably reacting with one another as they moved toward the surface and that they probably reached a maximum temperature at the top.

The subsequent work of Jaggar [56] has thrown much light on the observations of Day and Shepherd. It has already been explained in this paper in another connection (pp. 4 and 17) that Jaggar finds good evidence of the oxidation of combustible gases by air, through downward suction, when the level of the lake is falling, and by infalling surface crusts of lava which have absorbed air by reason of their vesicular nature. At the surface itself, careful observation reveals flames along the lava cracks.

If the heat effect of this oxidation is sufficiently great, the temperature ought to be highest at the upper surface of the molten lava. In January, 1917, Jaggar sounded the lava lake with a long iron pipe and found at two different points, one of them 30 feet from the shore, that the depth of the *thinner* lava was about 50 feet. At that depth, the pipe struck a layer too viscous for it to penetrate. A month later, when the lava lake subsided the shore line was found to be practically perpendicular, so that the impenetrable layer could not have been a part of a shelving shore. Further exploration of the lake revealed the fact that the temperatures were not only very variable but that they were no higher at a depth of several feet and that they reached their maxima where there was the most convincing evidence of rapid

[55] *Loc. cit.,* p. 601.
[56] *Am. J. Sci.,* **44,** 161, 1917.

oxidation. Thus the temperature of the lava under the surface crust of the lake, as determined by Seger cones in an iron pipe, was found to vary from 750° to 850° : in the "grottos," where rapid downward currents seemed to be drawing in air, the temperature rose above 1130°, and in the "blowing domes," which are built up of spattered lava through the agency of rapidly escaping gases, the temperatures reached 1250° to 1350° and were hottest where the gases came into contact with the outer air. Previous measurements by Shepherd and Perret had been made in "lava fountains"—points in the lake marked by a vigorous current of escaping gases. Here the temperature ranged from 1100° to 1185°.

Taking all the evidence together, Jaggar's case for surface oxidation at Kilauea is convincing. Probably the most important question we may ask concerning it is : *What proportion of the heat is supplied in this way?* It can hardly be supposed that the *principal* source of heat is from this cause; originally, of course, it could not have been so.

Little is known about surface combustion in volcanic craters generally. At Santorin, however, Fouqué[57] observed flames issuing from the crater in 1866, and his observation was confirmed by Schmidt.[58]

VI. VOLCANIC EXPLOSIONS.

Considerable diversity of opinion has been expressed on the cause of volcanic explosions. On the one hand, it has been held that they were the result of the sudden vaporization of vadose water or water included in the superficial strata of the earth, and on the other that they could only be caused by the expansion of gases which come from the magma itself.

I. Secondary explosions.

In the summer of 1902, while Mt. Pelée was in eruption, G. C. Curtis[59] observed on the Islands of Martinique and St. Vincent hundreds of explosions of various degrees of violence which were caused by the flow of rain water upon hot volcanic ejecta. This detritus, consisting of material all the way in size from dust to huge boulders, was piled up in the stream valleys in masses some-

---

[57] Santorin, Paris, 1867.

[58] "Vulkanstudien," p. 193, Leipzig, 1874.

[59] *Jour. Geol.*, xi, 199, 1903.

times 100 feet thick, the lower layers of which naturally preserved a high temperature for a long time. The explosions were brought about by the sudden flooding of the river beds by torrential tropical rains or by the rise of water following the caving in of ash beds which dammed up the stream channels.

Curtis saw at close range two eruptions of this sort of remarkable violence—one on the Sèche River, Martinique, and the other near the mouth of the Wallibou River, St. Vincent. The latter threw out a tremendous column of steam, ash and boulders to an estimated height of over 3000 feet. Some of the ash craters formed in this way were 40 feet deep by more than 160 feet in diameter. There is therefore no doubt that explosions of a purely secondary character, that is, due to the vaporization of surface water, and of great violence can and do occur under natural conditions.

Lacroix observed similar but less violent explosions at Martinique. Russell,[60] impressed especially by the evidence of Curtis, would explain tentatively all eruptive phenomena as the result of contact of the ground water with "highly heated rock rising from the depths of the earth." The peculiarly porous nature of many volcanic cones built up, as they often are, of porous and fragmental materials should make them exceptionally penetrable by water.

To what extent explosions in volcanoes are due to this cause is not yet known. A. L. Day[61] connects the explosions at Lassen Peak in 1914 and 1915 with the melting of the heavy snows which filled the former summit crater and which there attain great depth. To ascribe the activity of volcanoes of the Hawaiian or Strombolian type or even the "nuées ardentes" of Mt. Pelée to surface water alone (steam explosions) appears to stretch the hypotheses beyond the reach of any tangible support from existing records. Capillary phenomena (Daubrée effect) cease to be effective above the critical temperature of water and so appear to afford no aid in bringing ground water within the sphere of action of a column of liquid lava.

Gautier[62] holds an intermediate position between those who regard volcanic explosions as caused by the sudden contact of

[60] *National Geographic Mag.*, xiii, 416, 1902.

[61] Unpublished work.

[62] *Ann. des Mines*, (10) 9, 316, 1906, especially pp. 342, 368 and 369.

surface water and hot volcanic material and those who seek the cause of these explosions in the nature of the magma itself. He finds a necessary condition of all eruptive phenomena in the gases, especially the water, of the deep-seated rocks. Some of this water is a reduction product of the oxides in the magma by hydrogen from the depths of the globe, but another portion is supplied by descending meteoric waters which are taken up by rocks in place of the water they have already lost by volcanic heat.

The second essential condition of eruptive activity, according to Gautier, is the sudden access of heat to the plutonic rocks. This is brought about by a sudden subsidence of the earth's crust into the hot zone, thereby forcing molten lava into fissures of the plutonic rocks. The peculiar feature of Gautier's theory, *a sudden subsidence,* need not be considered here since it belongs to the mechanical side of the subject.

II. Primary explosions.

It is only in rare instances that much of scientific value has been learned from direct observation of volcanic explosions. The structure of pumice, one of the most characteristic products of explosion points clearly to the release of gas under pressure, while the torrential rains which so frequently accompany eruptive outbursts indicate the nature of the most important of the gases.[63] In view of all the evidence it seems impossible to avoid the conclusion that many of the major volcanic explosions are produced by gases direct from the magma, and that water is the chief of these gases.

If we entertain the hypothesis that explosions of this character are caused by the instantaneous oxidation of hydrogen or other combustible gas, it is impossible to conceive of conditions under which chemical action of this kind could proceed, for, while of course an abundant supply of combined oxygen exists in the magma itself, the conditions there are totally inadequate to effect a sudden union of the gases (p. 15). After a crater has once been opened, it is conceivable that combustible gases might be exploded with air. The proportion of the combustible constituents would have to be considerable. Not all volcanic gases could be exploded under any conditions unless we are wrong about the nature of the original gases. A further essential condition for explosion is that a mixture of the gas with air must be effected at a temperature *below*

---

[63] For an alternative view see p. 17.

the ignition point and that the mixture must subsequently be raised to that temperature. While this may be possible, it is difficult to picture such a thing in any convincing way. That large volumes of combustible gas may escape into the air and burn without explosion is a fact often manifested at gas wells.

Probably the best and most convincing evidence on the nature of primary volcanic explosions that we possess is the series of careful and systematic observations by Lacroix at Mt. Pelée in 1902–3. Here was an unusual opportunity and a rare observer. Phenomena like the following were witnessed repeatedly and studied by him in detail. The mouth of the crater at intervals roofed itself over with a dome of stiff viscous lava forced up from below. Lacroix tells us that the necessary and sufficient condition for the formation of a dome is that the lava should be very viscous. A dome is generally composed of highly siliceous rock, but a more basic and therefore more fusible lava would possess this essential characteristic at lower temperature. Pressure on the still incompletely solidified dome by the lava beneath it gradually thrust up a needle to a maximum height of hundreds of metres above the dome. Finally a sudden upthrust from below appeared to cause an explosive rupture of the shell and the projection of one of the remarkable red-hot clouds of gas, pumice and boulders which Lacroix describes so realistically. Lacroix [64] says that the only hypothesis which can be put forward to explain these explosions is a sudden expansion of gas beneath the shell of the dome. He believes that the most important of the gases is steam.

The effectiveness of steam as an explosive agent, long known to man, has been attested on a greater scale by the impressive evidence of Curtis. Captain Vernier, cited by Lacroix,[65] compares the disruptive force of steam at high temperatures with that of the high explosives. According to him one kilogram of water converted into steam at 1200° would exert a force sufficient to raise 391 kilograms of rock to a height of one kilometre.

Lacroix's keen observation, his painstaking labor in collecting facts, his judgment in sifting them and the many-sidedness of his effort have brought together a mass of testimony unrivalled for solidity in the annals of volcanology. Indeed it is doubtful

[64] " Montagne Pelée," p. 358.

[65] *Op. cit.*, p. 359.

whether *direct observation* of volcanic explosions will ever carry us much further. Of course many questions remain still unanswered, but Lacroix's conclusion in the case of Mt. Pelée that the crater explosions were caused by the expansion of magmatic gases, the chief of which is water, seems to me in accord with the best evidence we have on the nature and origin of the volcanic gases, and constitutes the best explanation of at least many major volcanic explosions.

In this brief survey the attempt has been made to give a general treatment of volcanism in its chemical aspects. While exceptions are not unlikely to occur in so complex a subject the following conclusions seem justified:

VII. SUMMARY.

1. The original volcanic gases can be traced back to the igneous rocks. Water is probably the most important of them.

2. The original volcanic gases are generally changed in composition by the time they reach the point of collection; in some cases they probably lose a portion of the strong acid gases: in most cases they become diluted by steam from surface water and by the atmospheric gases.

3. In some volcanic emanations the relations between the inert gases point to an atmospheric origin for these particular constituents; in others the inert constituents must either be of deep-seated origin or their original atmospheric relation has been changed by selective solubility in the magma.

4. Deville's laws respecting the variation in the composition of volcanic gases with the distance from an eruptive centre or with passing time are not supported by the great body of evidence.

5. There is evidence to show that a more or less abrupt evolution of gas from the magma occurs during crystallization, but it needs further support.

6. Chemical energy from shifting equilibria may have a considerable influence in prolonging the life of an eruption, but not in initiating or rejuvenating volcanic activity. Surface combustion in particular instances is probably an important factor in keeping up temperature.

7. Secondary volcanic explosions of great violence are undoubtedly produced by the access of surface water to hot volcanic ejecta. The primary explosions, according to the best evidence,

are the result of pressure from magmatic gases, not the result of chemical action.

APPENDIX.
THE ANALYSES OF VOLCANIC GASES.

A rather thorough search of the literature was made in the first place for the purpose of finding whether any relation whatever existed between the composition of volcanic gases and the temperature at which they issue from the ground. Then as the present paper at several points calls for the examination and comparison of the analyses of volcanic gases, it was thought best to bring the collected analyses together as an appendix to this article. F. W. Clarke[1] and F. von Wolff[2] have already brought together a considerable number of such analyses but neither collection approaches completeness. It was my first intention to include all analyses of volcanic gases in this compilation, but it soon became evident that there were many partial analyses which were not worth the space. Where a considerable number of analyses have been made in the same general locality at the same period, only representative ones are included. Otherwise it is believed that this collection is practically complete. Where a complete analysis of a gas, including the water, and a separate analysis of the fixed gases are both given in the literature, the latter analysis is generally included for purposes of comparison with other analyses

---

[1] "Geochemistry," *Bull. U. S. Geol. Survey*, 695, 1920, pp. 255-264.
[2] Vulcanismus (Stuttgart, 1914), Bd. I, pp. 555–560.

where the water is omitted. The analyses of gases from hot springs of well-known volcanic origin are here included as of importance in following out the volcanic processes to completion, so far as this is possible.

REFERENCES.

Analyses 1-7—Brun, "Exhalaison Volcanique," pp. 249-251 (Genève, 1911).

Analyses 8-19—Day and Shepherd, *Bull. Geol. Soc. Amer.*, **24**, 573, 1913.

Analyses 20-29—Shepherd, *Bull. Hawaiian Volcano Obs.*, vii, 94, 1919.

Analyses 30-43—Shepherd, *Bull. Hawaiian Volcano Obs.*, ix, 86, 1921.

Analyses 44-45—Shepherd, *Bull. Hawaiian Volcano Obs.*, viii, 65, 1920.

Analyses 46-53, 68-70, 72-74, 77-79, 81-83, 92, 95, 96, 102, 103, 105, 108, 112, 114, 116-119, 124, 126, 127, 130-138—Deville and Leblanc, *Ann. Chim. Phys.*, (3) **52**, 5, 1858.

Analyses 54, 59, 61, 62, 64, 75, 76, 84, 85, 87, 89—Fouqué, *C. R.*, **61**, 734, 1865.

Analyses 104, 106, 107, 109, 113, 115, 122, 125, 128, 129—Fouqué, *C. R.*, **61**, 421, 1865.

Analyses 139-151—Fouqué, *C. R.* **61**, 564, 1865.

Analyses 152-166—Fouqué, *C. R.*, **64**, 184, 1865.

Analyses 60, 63, 65-67, 71, 86, 88, 90, 91—Gorceix, *C. R.*, **75**, 154, 1872.

Analyses 167-180—Gorceix, *C. R.*, **75**, 270, 1872.

Analyses 181-182—Gorceix, *C. R.*, **78**, 1309, 1874.

Analyses 93, 94, 97-101, 110, 111, 120, 121, 123—Silvestri, *Neues Jahrb. Min.*, 1870, 257.

Analyses 55-58—Gautier, *C. R.*, **148**, 1708, 1909.

Analysis 80—Gautier, *C. R.*, **149**, 84, 1909.

Analysis 183—Bunsen, *Zeitschrift f. Vulk.*, I, 92, 1914-15.

Analyses 216-225—Bunsen, *An. Chim. Phys.*, (3) **38**, 260, 1853.

Analyses 184-193—Kharichkov, *Chem. Tech. Zeit.*, **29**, 126. See also *Zeitschrift f. Vulkanologie*, I, 92, 1914-15.

Analyses 195-198—Moissan, *C. R.*, **135**, 1085, 1902.

Analyses 199-201—Moissan, *C. R.*, **138**, 936, 1904.

Analyses 194, 202-215—Hempel, *Zeitschrift f. Vulk.*, I, 150, 1914-15.

Analyses 226-241—Christensen, *Tidskr. Phys. and Chem.*, Copenhagen, 10, 225, 1889.

Analyses 242-274, 275-307—Thorkelsson, *Mem. Acad. Royal de Danemark*, 8, 182, 1910. (*Kgl. Danske Vidensk. Selsk. Skrifter.*)

Analyses 275-291 and 275a-291a—Allen and Zies, unpublished.

Analyses 275a-291a—Allen and Zies.

Analyses 308-313—Brun, "Exhalaison Volcanique," p. 202.

Analysis 314—Fouqué, *C. R.*, **66**, 915, 1868.

Analyses 315-318—Brun, "Exhalaison Volcanique," p. 224.

ANALYSES OF VOLCANIC GASES.

HAWAII	Date	No.	Temp.	H_2O	CO_2	CO	CH_4	C_2H_6	C_2H_4	H_2	Cl_2	F_2	H_2S	SO_2	SO_3	S_2	N_2	A	He	O_2
Fumarole, 150–200 metres N. of Crater.	1910	1	340	30	3.												67.[a]			
		2	340	8.5	15.3												76.2[a]			
Sulphur Bank 4 kilometres from Crater	1910	3	96		16.												84.[a]			
		4	96		33.												67.[a]			
		5	96		23.3												76.7[a]			
		6	96		10.7												89.3[a]			
		7	96		17.												83.[a]			
		8			23.8	5.6	none	none	none	7.2				none			63.3	none		
The Crater	May 1912	9			58.0	3.9	none	none	none	6.7				1.5			29.8	none		
		10			62.3	3.5	none	none	none	7.5				12.8			13.8	none		
		11			59.2	4.6	none	none	none	7.0				none			29.2	none		
		12			73.9	4.0	none	none	none	10.2				none			11.8	none		
The Crater	Dec. 1912	13		26.2[b]	49.6[b]						trace[b]	none[b]			none[b]		24.1[b]			
		14		26.6[b]	33.7[b]						none[b]	none[b]			7.6[b]		32.1[b]			
		15		29.7[b]	45.4[b]						trace[b]	none[b]			3.5[b]		21.3[b]			19.54[b]
		16		9.74[b]	3.64[b]										.37[b]		66.71[b]			18.2[b]
Devil's Kitchen	1912	17[d]		25.49[b]	5.8						.0513[c]	.0079[c]			1.328[c]		76.0[b]			14.58[b]
		18[c]			8.12[b]						.0298[c]	none[d]			.59[b]		51.20[b]			
100 metres S. of auto road terminal.	1912	19		7.81[b]	9.64[b]						none				0.51[b]		63.85[b]			18.18[b]
The Crater	1917	20		67.99	2.65	1.04				4.22	udt			.16		.70	23.22	udt		
		21		38.48	17.95	.36				1.35	udt			3.51		.49	37.84	udt		
		22		17.97	33.48	1.42				1.56	.17			29.83		1.79	12.88	.45		
		23		77.50	11.12	3.92				1.42	.02			—		8.61	—	.51		
		24		64.71	9.54	1.12				1.53				9.90		2.72	10.47	—		
		25		89.77	1.97	.82				.21				.95		2.70	3.50	.07		
		26		64.18	17.25	.62				.76	.25			9.75		1.07	5.88	.18		
		27		75.08	15.27	.45				.70				6.98		.87	.68	.14		
		28		59.07	8.37	.82				1.82	1.01			16.80		2.48	8.92	.29		
		29		89.93	1.54	.43				.37	1.34					3.56	2.44	.39		
The Crater	1919	30		75.09	5.79	.00				.00	4.08			4.76	2.41	.00	7.92	udt		
		31		80.31	6.63	.22				.15	1.11			3.23	5.51	.00	2.37	.56		
		32		84.98	6.79	.14				.17	.62			1.38	3.43	.15	2.33	.00		
		33		78.71	.87	.16				.07	.03			0.01	.13	.00	20.01	.00		
		34		36.18	47.68	1.46				.48	.04			11.15	.42	.04	2.41	.14		
		35		50.88	16.44	.11				.10	.03			13.57	3.56	.05	15.03	.21		
		36		61.56	20.93	.59				.32	.00			11.42	.55	.25	4.13	.31		
		37		97.09	1.42	.05				.08	.03			.51	.00	.07	.68	.05		
		38		67.52	16.96	.58				.96	.10			7.91	2.46	.09	3.35	.66		
		39		76.84	14.81	.47				.17	.00			3.65	1.03	.10	2.91	.00		
		40		73.89	11.53	.13				.10	.10			6.14	1.70	.03	6.20	.16		
		41		66.25	18.03	.56				.67	.08			8.53	2.53	.15	3.11	.08		
		42		79.31	11.61	.37				.58	.05			6.48	.00	.24	4.50	.04		
		43		61.88	17.55	.74				8.3	.13			10.81	3.22	.22	10.80	.12		
Mauna Loa Lava Flow	Oct. 1919	44		75.44	3.84	.03				.01				1.22	2.08			.58		
		45		67.43	6.42	.19								1.95	8.12	—	15.39	.42		

ANALYSES OF VOLCANIC GASES —Continued.

VESUVIUS	Date	No.	Temp.	H_2O	CO_2	CO	CH_4	C_2H_4	C_2H_g	H_2	HCl	HF	H_2S	SO_2	SO_3	S_2	N_2	A	He	O_2
East edge of Great Crater of 1850	1856	46	154°	consider-able pro-portion	none						pres-ent			2.6	pres-ent		78.7			18.7
N. W. of small cavity of 1850	1856	47	154		none						pres-ent			2.4	pres-ent		77.9			19.7
N. E. rim of Great Crater of 1850.	1856	48	66-70		none									1.7			78.0			20.3
Gulf of 1854	1856	49	74		none									.7			70.8			19.5
	1856	50	74											2.6			78.5			18.9
	1855	51	89		9.52								none				72.32			18.16
Centre of Plain																				
End of small lava flows of 1842-1848	1856	52	60		1.3								none	none			78.7			20.0
N. W. of smallest excavation of 1850	1856	53	67		3.15								none				77.30			19.25
Edge of Great Crater	1865	54	90		4.80	none	none			1.21	0.78		none	none			75.60			19.60
Near summit of cone	1906	55	300+	67.71	11.03	none	none			trace	trace		none	none			15.10f			3.72
	1906	56	300+	62.44	6.68												24.88g			6.0
Valley N. E. of Crater	1907	57	280-300	72.69	0.80	.15	none			.54	none		none	none			21.23			4.59
Same fumarole as No. 57	1907	58	280-300	77.76	0.66	.02	?			.02	none		none	none			17.62	.213		3.68
PHLEGRÆAN FIELDS																				
Torre del Greco	1865	59			85.38		.05		.05				none				9.38			2.85
Torre del Greco, flow of 1694	1869	60			00.2		2.8						none				6.2			0.8

a. Includes oxygen.
b. By weight.
c. Grams in water condensed in separate sample.
d. No ammonia in the water condensed.

e. Sulphur trioxide, 0.050 gram in separate sample of water in which chlorine and fluorine were sought.
f. Includes argon, etc.
g. Includes all unsaturated hydrocarbons.

ANALYSES OF VOLCANIC GASES—Continued.

PHLEGREAN FIELDS—Cont'd	Date	No.	Temp.	H₂O	CO₂	CO	CH₄	C₂H₆	C₂H₄	H₂	HCl	HF	H₂S	SO₂	SO₃	S₂	N₂	A	He	O₂
Santa Lucia	1865	61			95.66								trace				4.34[h]			8.52
Chiatamone	1865	62			65.34								trace				22.53			1.7
Chiatamone	1869	63	27.2		82.1		3.22		.94								16.2			1.11
Grotta di Zolfo	1865	64			94.42		.08		0.88				trace				2.45[l]			0.8
Grotta di Zolfo, exterior	1869	65	27.0		87.7								5.0				6.5[l]			0.7
Grotta di Zolfo, interior	1869	66			87.8								5.7				5 7			
Grotta di Zolfo	1869	67			92.3[j]		4.3										2.7			0.5
Great Solfatare of Pouzzoles.	1856	68	88-92	enormous mass	5.7									none				75.9			18.4
Great Solfatare of Pouzzoles.	1856	69	88-92	enormous mass	0.7									6.8				92.5[h]			
Great Solfatare of Pouzzoles.	1856	70	88-92	enormous mass	none		none	none	none	none				24.7				60.8			14.5
Great Solfatare of 1867.	1869	71	115	extremely aqueous	88.8								7.0				4.5			0.7
Little Solfatare, Orifice 2.	1856	72	93-93.5	extremely aqueous	2.9								none at lab.				78.85			18.25
Little Solfatare, Orifice 2.	1856	73	72-76	aqueous	19.2								none at lab.				64.6			16.2
Little Solfatare, Orifice 3.	1856	74	90-91	extremely aqueous	30.5								none at lab.				60.0			8.9
Little Solfatare of Pouzzoles.	1865	75	96		56.67								11.43				26.18			5.72
Little Solfatare of Pouzzoles.	1865	76	77.5		15.09								none				69.40			15.51
Lago d'Agnano. Orifice 1.	1856	77	71-87		7.25								positive test				73.53			19.22
Stufe de San Germano, Orifice 1.	1856	78	83-93		3.3								positive test				76.6			20.1
Stufe de San Germano, Orifice 2.	1856	79	72-80.7	96-97	14.52		none	none	none	none			positive test				67.83			17.65
Lago d'Agnano.	1907	80			96.52		.12	none	none	.015								2.87	.028		0.46
Lago d'Agnano.	1856	81	29		67.1	none												26.4			6.5
Grotte du Chien	1856	82	29		73.6													21.1			5.3
Lago d'Agnano.	1856	83	32		81.1													15.1			3.8
Grotte d'Ammoniac.	1865	84			97.47													2.01			.52
Acqua Media, Spring.	1865	85			47.67								trace				52.33			none
Acqua Media. Spring, Media.	1869	86	25		70.8								trace				29.6			0.6

ANALYSES OF VOLCANIC GASES—Continued.

PHLEGREAN FIELDS—Cont'd	Date.	No.	Temp.	H2O	CO2	CO	CH4	C2H6	C2H4	H2	HCl	HF	H2S	SO2	SO3	S2	N2	A	He	O2
Acqua ferrata del Pozillo.	1865	87	27		36.21												63.79			0.7
	1869	88			29.1												70.2			
Spring Soforo ferrata.	1865	89			33.65								none				66.35			none
Acqua ferrata e solforea (same as 89?)	1869	90	26		44.4								3.1				52.2			0.2
Telese Baths.	1869	91	24		90.4								5.1				4.0			0.5
ETNA																				
Rim of upper Crater.	1856	92*	99								94.2		positive test	5.8	present					
Crater B, fumarole.	1865	93			5.0								.45				77.28			17.27
Crater D, fumarole.	1865	94			1.61								.35				79.07			18.97
Initial fissure of 1838.	1856	95	41–82.5	about 80%	12.1												73.1			14.8
	1856	96	41–82.5		9.3												90.70			
Fumarole on fissure.	1863	97	150–180		50.5								11.9				30.5			7.1
	1864	98	150–180		48.9								10.6				35.0			5.5
(Same day as No. 99.)	1865	99	150–180		66.2								12.7				16.7			4.4
	1865	100	150–180		32.0								9.4				51.8			9.8
(Same day as No. 99.)	1865	101	150–180		37.8								5.4				47.2			9.6
SICILY																				
Salinelle of Paterno Acqua Rossa.	1856	102	19.8		97.9												2.1a			0.97
	1856	103	19.8		93.23												5.8			.40
	1865	104			97.9	none	none	none	none	none							1.70			
Paterno Val Corrente	1856	105			67.0	32.49k														.51
Acqua Rossa of Val Corrente.	1865	106			99.07												.75			.18
Mud volcano Val Corrente or San Biagio.	1865	107			74.00	.	3.77			0.90			none				19.47			2.78
Salinelle of Paterno.	1856	108	ordinary		90.7		5.0			.50			none				3.3			1.0
	1865	109			95.35		1.12			.55			none				2.94			.58
	1865	110			95.42		.96										2.97			.77
Salinelle of Paterno (average of several).	1865	111	27–46		92.53		1.40			.99			.30				4.70			.12
Paterno, Spring of Valancella.	1850	112			99.2												.8			none
	1865	113			90.78		.68										.18			.04
Lago Palici.	1850	114			94.7												3.52			1.1
	1865	115			93.40		1.45			.13							5.14			0.68

*This analysis includes only gases absorbed by NaOH

f. Includes argon, etc.

h. Includes marsh gas and oxygen.

i. Includes methane.

j. Includes hydrogen sulphide.

k. Includes little hydrocarbon.

Analyses of Volcanic Gases—Continued.

SICILY	Date	No.	Temp.	H_2O	CO_2	CO	CH_4	C_2H_6	C_2H_4?	H_2	HCl	HF	H_2S	SO_2	SO_3	S_2	N_2	A	He	O_2
Macuba of Xirbi	1856	116			.93		97.95											1.12			
	1865	117			.70		73.73			trace								20.40			5.17
Small cone of Terrapilata	1856	118			6.34		93.66			trace								none			12.30
	1865	119			0.26		40.98											46.46			none
	1865	120			1.8													98.2			none
Acqua Santa of Limosina	1856	121			1.6									none				98.4			
	1865	122			2.10													96.60			1.30
	1866	123			4.35													88.70			6.95
Macluba of Girgenti	1856	124			1.15		90.4							none				6.75			1.70
	1865	125			1.65		87.23			5.74				0.2				3.74			0.69
Spring of Santa Venerina	1856	126	22.7		3.1		95.5[1]														1.2
	1856	127	22.7		4.2		83.62											12.18			none
Spring of Segeste	1865	128			3.13		71.76			3.70				trace				22.15			1.18
	1865	129			.32									trace				88.12			11.56
LIPARI ISLES *Vulcano*																				
Bottom of crater.	1856	130	94		none							positive test		•	21.3			63.63			15.07
	1856	131	94		none							none			27.50			58.48			14.02
	1856	132	94		none										84.2			15.8[a]			
	1856	133	82		none										69.6			24.9			
North Slope.	1856	134	84		9.8													6.8			5.5
	1856	135			2.5													7.9[a]			0.6
Acqua Bollente.	1856	136	25		86.0									82.8	89.6			13.6			0.4
Near Works.	1856	137	25		83.0													17.0			none
Near Works. Chem.	1856	138	25		86.0													14.0			none
Interior of Great Crater.	1865	139	360+		23.40							73.8[n]						2.28			.52
Interior of Great Crater.	1865	140	250		22.0							66.0[m]						9.6			2.4
Interior of Great Crater.	1865	141	150		59.62							27.19[m]						10.99			2.20
Interior of Great Crater.	1865	142	100		68.8							7.3		10.7				11.2			2.7
Interior of Great Crater. (Same as Acqua Bollente).	1865	143	100		63.59							none		trace				29.13			7.28
Small pool near the sea.	1865	144	86		77.02									17.55				4.73			.70
Seashore near No. 144.	1865	145	—		07.12									trace				2.40			.48

ANALYSES OF VOLCANIC GASES—Continued.

	Date	No.	Temp.	H₂O	CO₂	CO	CH₄	C₂H₆	C₂H₄	H₂	HCl	HF	H₂S	SO₂	SO₃	S₂	N₂	A	He	O₂
SICILY *Continued*																				
50 metres from No. 144.	1865	146			86.76								trace				11.35			1.89
200 metres from No. 144.	1865	147			72.34								none				25.53			2.13
250 metres from No. 144.	1865	148			38.79								none				57.42			3.79
Punaria Near seashore.	1865	149			90.53								6.44				2.51			0.52
Small lagoon.	1865	150			97.0								trace				2.51			0.49
Bottaro between Stromboli and Lipari.	1865	151			72.3								trace				22.6			5.1
SANTORIN Near Isle of Beka Palaea-Kaméni	1866	152	50-66		1.49		.42			none			trace				79.64			18.45
St. Nicholas.	1866	153	19		78.44		.64			none			none				17.55			3.37
	1866	154	69		50.41		2.95			16.12			trace				30.32			0.20
	1866	155	65		90.78								trace				8.34			.88
Nea-Kaméni.	1866	156	56		95.37								trace				4.11			.49
Pool between Nea-Kaméni and Aphroessa.	1866	157	50		86.76								trace				11.23			2.01
	1866	158	50		84.85								trace				12.81			2.31
Between Aphroessa and a point S. E. of Nea-Kaméni.	1866	159	61		35.60		.81			30.09			trace				32.04			1.46
Near N. bank of Aphroessa.	1866	160	60		0.07		.71			1.62			trace				76.04			21.56
West slope of George.	1866	161	160	consid-erable	17.28		.49			trace			1.64				66.47			14.12
Foot of cone of George.	1866	162	87	consid-erable	5.88								.42				74.71			18.99
	1866	163	122	consid-erable	12.24								.90				70.45			16.41
Between George and Aphroessa.	1866	164	73	consid-erable	37.04		.43			27.10			trace				35.02			.41
	1866	165	75		37.24		.47			28.12			trace				33.66			.51
	1866	166	78		36.42		.86			29.43			trace				32.07			.32
	1866	167	60		90.0		trace			none			none				0.1			0.0
Port of Vulcano.	1870	168	55		87.0		trace			none			none				13.0			none
	1870	169	19		77.3		trace			none			none				22.6			none
	1870	170	49		97.1		trace			none			none				2.0			none
	1871	171	49		95.9		trace			none			none				3.4			0.5
	1870	172			37.5												60.8			1.7
	1870	173	46		78.0												21.5			0.5
	1870	174	30		86.0												13.0			1.0
	1870	175	28		43.7												53.6			2.7

l. Includes nitrogen.

m. Includes sulphur dioxide.

ANALYSES OF VOLCANIC GASES—Continued.

	Date	No.	Temp.	H_2O	CO_2	CO	CH_4	C_2H_6	C_2H_4	H_2	HCl	HF	H_2S	SO_2	SO_3	S_2	N_2	A	He	O_2
SANTORIN *Continued*																				
Port of George.	1870	176	19		98.8		trace			none			trace				1.8			0.4
Base of cone of George	1870	177			63.3		0.5			0.8							28.6			6.5
200 metres from cone of George.	1870	178	115		68.5						19.4	.		12.0						
Ravine between Cone of George and lava flow.	1870	179	110		98.5					none				0.4						
Port of St. Nicholas.	1870	180	30		97.6		0.1			none	1.0		none				1.9			0.4
GRECIAN ARCHIPELAGO																				
Nisyros, old volcano, adventitious fumarole.	1873	181[i]			97.5[j]		1.0			trace			57.1				1.5			
	1873	182			38.4		0.4			1.5							2.4			
RUSSIA																				
Kertsch Peninsula (Crimea) 183-193 Mud Volcanoes. Titarowka.Taman Peninsula.		183			3.5	—	92.24	—	4.26	—			—				—			—
Baladsary.		184[n]			0.2	1.0	80.6	.0	.0	10.2			trace				6.0			2.0
		185[n]			3.7	3.0	64.7	.0	4.2	15.4			trace				4.0			0.9
		186[n]			6.0	.0	18.86	15.3	3.7	.0			trace				53.5			2.2
Bosdag.		187[n]			4.8	0.6	53.5	.0	.0	.0			0.25				41.05			0.8
Arbat.		188			3.0	1.0	53.3	.0	.8	.0			.0				35.7			5.3
Adsi Kabul.		189[a]			4.8	1.2	81.6	.0	1.0	.0			.0				10.4			1.0
Keljany.		190[n]			4.4	3.6	50.05	.0	2.2	.0			trace				34.4			5.4
Marassy.		191[n]			4.0	.0	76.05	.0	0.4	.0			.31				18.89			0.2
		192[n]			.28	.0	41.3	45.6	0.28	.0			trace				9.68			2.86
		193[n]			1.0	.0	52.2	5.0	.0	.8			.0				39.7			1.3
TRANSCAUCASIA Baku. Sacred Fire.	1902	194[o]			1.7		88.0	4.6					none				4.3			0.6
WEST INDIES Martinique, Mt. Pelée, River	1902	195	327–419	saturated	16.80[p]					11.60[q]							59.20[f]			11.60
	1902	196	327–419	saturated	13.58[p]					11.00[q]							64.10[f]			11.11
	1902	197	327–419	saturated	16.42[p]					10.64[q]							60.53[f]			12.14
	1902	198	327–419	saturated	15.38[p]					15.30[q]							55.65[f]			13.67
Blanche.	1902	199	327–419	saturated	15.38	1.60	5.46		none	8.12	trace		none			trace	54.94	0.71		13.67

ANALYSES OF VOLCANIC GASES—Continued.

	Date	No.	Temp.	H_2O	CO_2	CO	CH_4	C_2H_6	C_2H_4	H_2	HCl	HF	H_2S	SO_2	SO_3	S_2	N_2	A	He	O_2
WEST INDIES *Continued.*																				
Guadeloupe. Fumarole of the North.	1904	200	96	saturated	52.8	none	none	none	none	none	trace		2.7			trace	36.07	.73		7.5
Guadeloupe Fumarole Napoleon	1904	201	—	saturated	69.5	none	none	none	none	none	none		4.5			trace	22.32	.68		2.7
COLOMBIA, S. AMERICA.																				
Mud volcano, near Turbaco, Cartagena.	1868	202			4.1		72.5	7.8	none	0.4										3.2
	1868	203					100.													
Mud volcano, near Turbaco, Cartagena.	1868	204			1.5		97.6	0.5	none	0.3										
	1868	205					98.7													
Mud volcano del Tigre.	1868	206					100.	1.8												1.0
	1868	207					93.8													
Puracé Crater.	1868	208	86.6	much	2.1									none						12.9
Puracé Solfatara.	1868	209			98.2									0.4						0.6
Puracé Solfatara.	1868	210			95.6									0.3						0.5
Puracé Hot Spring.	1868	211			83.6								13.9							
	1868	212			84.9								9.4							
Azufral Springs.	1868	213			80.5								8.8							
	1868	214			87.1								11.6							
Ecuador Boundary, Boca del Mundo.	1868	215		50.1	33.3								5.9							0.3
ICELAND																				
Hekla lava flows of 1845.	1846	216			'1.01	none	none					none		none	none			78.90			20.09
Krisuvik solfatara	1846	217			87.43	none	none			4.30			6.60				1.67			
Same gas as 217. Krisuvik, 2d fumarole.	1846	218		82.3	15.47	none	none			.76			1.17				.30			
marole.	1846	219			88.24	none	none			4.10			6.07				.60			
4 league from Krisuvik, small puddles.	1846	220			79.07	none	none			4.72			15.71				.50			
	1846	221			88.54	none	none			7.87			1.79				1.80			
	1846	222			86.92	none	none			8.36			3.28				1.44			
Haukadalr, Great Geyser.	1846	223			8.92	none	none			6.59			0.38				84.11			none
Hekla, Great Crater, 1st fumarole.	1846	224			2.44	none	none				none		none	1.54			81.81			14.21

n. Traces of phosphine were found in Nos. 185, 189, 190; but none in Nos. 184, 186, 187, 191, 192, 193.
o. Contains vapors, 0.8
p. Absorbed by caustic potash.
q. Combustible gas.

ANALYSES OF VOLCANIC GASES—*Continued.*

ICELAND Continued.	Date	No.	Temp.	H₂O	CO₂	CO	CH₄	C₂H₆	C₂H₄	H₂	HCl	HF	H₂S	SO₂	SO₃	S₂	N₂	A	He	O₂
2nd fumarole.	1846	225			.56	none	none				none		none	none			82.58			16.86
Krisuvik fumarole	1871	226															81.0			19.0
Krisuvik fumarole	1871	227		99.7													.24			.06
Krisuvik fumarole (2nd sample.)	1871	228															86.65			19.35
Myvatns, Oraefi, lava fissure.	1876	229			3.40												77.35			19.25
Krisuvik, solfatara.	1871	230			46.25					5.52			46.86				1.37			
Krabla, N. E. of Myvatns solfatara.	1871	231			68.80					15.59			5.89				9.72			
Krabla a second solfatara.	1871	232			63.52					11.71			13.94				10.83			
Krabla, a second solfatara.	1871	233			71.99					9.30			14.55				4.16			
Krabla, a second solfatara.	1871	234		99.6000	.2850					.0372			0.582				.0166			
Reykjahlid (or Námafjeld) solfatara.	1876	235			59.24					7.94			26.32				6.50			
Reykjahlid mud-pool.	1871	236			44.97					25.49			15.78				13.76			
Reykjahlid mud-pool.	1871	237			52.00					27.02			19.26				1.72			
Reykjahlid mud-pool.	1871	238		98.5	.78					.40			.29				.03			
Reykjahlid mud-pool.	1876	239			47.59					28.53			21.64				2.24			
Reykjahlid mud-pool.	1876	240			48.58					27.82			21.85				1.75			
Reykjahlid mud-pool.	1876	241			70.36j		none			27.73			12.6				1.91			none
Krafla No. 1.	1906	242	86		80.9		none			3.5			13.9				3.0f			none
Krafla No. 2.	1906	243	82		73.5					9.3							3.3f			
Námafjall No. 1.	1906	244	76		37.5		none			49.0			2.2				5.9f			none
Námafjall No. 4.	1906	245	90		30.0					none			18.4				2.6f			none
Reykjahlid No. 1	1906	246	44		.02		none			none			none				78.9			21.1
Reykir No. 1.	1906	247	62		none		none			none			none				98.49	1.48	.0132	none
Reykir No. 2.	1906	248	66.5		none		none			none			none				98.36	1.60	.0140	none
Reykir No. 3.	1906	249	64.2		none		none			none			none				100.f			none
Reykir No. 4.	1906	250	65		none		none			none			none				100.f			none
Reykir No. 5.	1906	251	17.3		none		none			none			none				98.34			none
Hveravellir No. 2	1906	252	95		79.5		0.9			none			2.8				16.5	1.61	.0146	none
Hveravellir No.10	1906	253	77		44.9		1.4			none			none				46.7f	.294	.0050	7.0
Hveravellir No.27	1906	254	82		40.0		1.5			none			none				51.5f			7.0
Hveravellir No.16	1906	255	93.5		46.7		1.5			0.7			none				45.7f			5.4
Hveravellir No.25	1906	256	81		77.8		1.0			none			none				20.6	.441	.0063	0.2

ANALYSES OF VOLCANIC GASES—*Continued.*

	Date	No.	Temp.	H₂O	CO₂	CO	CH₄	C₂H₆	C₂H₄	H₂	HCl	HF	H₂S	SO₂	SO₃	S₂	N₂	A	He	O₂
ICELAND *Continued*																				
Kjadlraun No.2.	1906	257	88		0.1		none			none			none				70.2[f]			20.7
Kerlingarfjöll No.2.	1906	258	92		71.1		0.3			11.7			14.4				2.5[f]			none
Kerlingarfjöll No.3.	1906	259	94		66.9		0.9			21.7			7.4				3.1[f]			none
Kerlingarfjöll No.4.	1906	260	91.5		70.7		0.7			14.5			13.1				1.0[f]			none
Grafarbakki No.1	1906	261	95		6.4		0.8			none			none				90.0	1.68	.0104	1.1
Grafarbakki No.2	1906	262	97.5		3.7		0.6			none			0.1				93.4[f]	2.15	.0195	none
Grafarbakki No.3	1906	263	97.		1.3		0.9			none			none				97.7[f]			0.1
Laugarás No.1	1906	264	96.		none		0.7			none			none				97.4	1.93	.0104	none
Laugarás No.2	1906	265	98.5		none		0.7			none			none				99.3[f]			none
Laugarás No.3	1906	266	93		none		0.5			none			none				97.4	2.1	—	none
Reykjafoss No.1	1906	267	93		27.0		0.2			2.5			none				67.9	1.36	.0103	1.0
Reykjafoss No.2	1906	268	91		87.9		0.3			0.6			6.7				4.5[f]			none
Reykjafoss No.3	1906	269	95		85.6		0.3			1.4			5.7				7.0[f]			none
Reykjafoss No.4	1906	270	99.4		84.5		0.2			none			12.0				3.3[f]			none
Hengill No.1	1906	271	91.5		73.4		0.3			13.5			11.0				1.8	.0113	.00059	none
Hengill No.2	1906	272	75.5		79.7		0.4			13.2			3.9				2.7[f]			none
Hengill No.3	1906	273	91		67.0		0.6			17.2			11.2				3.9	.088	.0020	none
Hengill No.4	1906	274	97		72.0		0.9			16.4			7.4				3.3[f]			none
KATMAI *Ten Thousand Smokes.*[r]	1910	275	95	99.97	.005	.000	.000						.007[s]				.017[f]			.001
		275a		—	17.5	.5	.2						23.6[f]				57.1[f]			1.1
		276	244	99.99	.004	.000	.000						.002[s]				.003[f]			.000
		276a		—	10.7	.1	.2						23.0[s]				35.5[f]			0.5
		277		99.93	.042	.000	.000						.010[s]				.018[f]			.000
		277a		—	59.7	.2	.1						14.2[s]				25.0[f]			0.8
Lower Valley.		278	255	99.96	.015	.000	.000						.010[s]				.015[f]			.000
		278a		—	36.9	.2	.1						24.7[s]				37.4[f]			0.7
		279	177	99.96	.003	.000	.000						.019[s]				.018[f]			.000
		279a		—	6.8	.1	.0						17.2[s]				46.0[f]			0.9
		280	68	99.95	.001	.000	.000						.021[s]				.021[f]			.000
		280a		—	8.6	.2	.1						13.2[s]				47.7[f]			0.2
		281	251	99.60	.000	.000	.000						.000[s]				.311[f]			0.3
		281a		—	0.2	.0	.2						1.0[s]				77.9[f]			20.7
Nova Rupta Basin.	1910	282	244	99.01	.017	.000	.007													.001
		282a		—	18.6	.8								.025[s]				.024	.000		1.0
		283	103	99.90	.038	.000	7.1						24.7[s]				24.00	.31		.005
		283a		—	38.1	.6	.002						.028[s]				.000	.000		5.1
		284	114	99.91	.018	.6	3.6						17.1[s]				15.73	.17		.001
		284a		—	30.8	.000	.068						.012[s]				.019	.000		2.0
		285	200	99.40	.132	.2	11.1						7.2[s]				8.10	.10		.006
		285a		—	72.0	.008	.160						.015[s]				.170[f]			1.0
		286	238	98.60	.986	.008	12.1						3.2				12.8[f]			.014
		286a		—	70.1	.6															1.0

r. All analyses marked with *numbers only* (275-201) will be seen to include water, while those marked *a* are analyses of the fixed gases corresponding. Thus, 275a is an analysis of the fixed gas of 275. These analyses are recorded separately for comparison with analyses so frequently occurring in the literature in which no account of the water is taken.

s. Includes hydrogen.

ANALYSES OF VOLCANIC GASES—*Continued.*

	Date	No.	Temp.	H₂O	CO₂	CO	CH₄	C₂H₆	C₂H₄ᵍ	H₂	HCl	HF	H₂S	SO₂	SO₃	S₂	N₂	A	He	O₂
KATMAI *Ten Thousand Smokes*																				
Upper Valley.	1919	287	96	99.95	.007	.000	.000						.035ᵘ				.006	.000		0.000
		287a		—	14.8	.6	1.1						70.9ᵍ				11.62	.18		.8
		288	253	99.96	.008	.000	.000						.027ᵘ				.004	.000		.000
		288a		—	20.6	.2	.6						67.9ᵍ				9.48	.12		1.1
Broken Mt. Valley.	1919	289	122	99.70	.011	.000	.000						.020ᵘ				.268	.000		.000
		289a		—	3.6	.1	1.0						6.7ᵘ				88.41	.99		0.2
Knife Creek Valley.	1919	290	98	99.94	.006	.000	.000						.051ᵘ				.002	.000		.000
		290a		—	10.2	.2	.6						84.7ᵘ				3.95	.05		0.3
	1919	291	440	99.96	.013	.000	.001						.022ᵘ				.004	.000		.000
		291a		—	33.6	.8	1.9						53.9ᵍ				9.26	.14		0.4
(Approximate Determinations) Ten Thousand Smokes.	1917	292									.006	0.003	0.006							
		293									.006	.003	.0007							
		294									.024	.052	.016							
		295									.057	.041	.092							
		296									.282	.024	.008							
		297									.083	.029	.012							
		298									.086	.005	.006							
		299									.013									
		300									.136									
		301									.042	.081	.077							
		302									.059	.033	.012							
		303									.008	.006	.022							
		304									.566	.099	.095							
		305										.003	.017							
		306									.241	.041	.026							
		307									.150	.033	.017							
CANARY ISLANDS Pico de Teyde north fumarole.	1907	308	83		70.8												24.1ᵘ			5.1
		309	83		63.9												31.3ᵘ			4.8
		310	83		63.9												31.9ᵘ			4.2
Pico de Teyde South fumarole.	1907	311	83		67.6												28.8ᵘ			3.6
		312	83		70.1												25.8ᵘ			4.1
		313	83		71.1												26.0ᵘ			2.0
AZORES The Sea Near Island of Terceira.	1867	314			2.27		16.75			.32							68.45			12.21
JAVA Papandajan same fumarole.	1908	315	192		16.8									46.7			31.4			5.1
		316			24.									30.			38.			8.
		317			10.									26.			51.ᵒ			13.
		318			17.									20.			63ᵃ.			

t. Water is taken into account in these determinations. They are comparable with the determinations in Nos. 275-291.
u. Includes other unabsorbable gases.
v. Water condensed from this fumarole contained 4.630 g. per liter hydrochloric acid; also some ammonium chloride. No H₂SO₄.

SOME APPLICATIONS OF THE MICROSCOPE IN RESEARCH.*

BY

HENRY LEFFMANN, A.M., M.D.

Lecturer on Research, Philadelphia College of Pharmacy and Science.
Member of the Institute.

THE microscope in its present form is one of the most perfect and useful instruments available in research. Its construction may be said to date from the closing years of the seventeenth century, although the general idea of magnification by curved glasses and mirrors was applied long before. While magnification is the basis of the instrument, its usefulness would be much restricted if that property alone was available. Newton's discovery of the composite nature of light gave a strong impetus to both practical study and theoretic suggestion in connection with all forms of optical instruments. Newton believed that refraction and dispersion were commensurate in all cases, and declared that it was impossible to construct a lens which would produce a colorless image. It was discovered, however, that substances of the same refractive often have different dispersive powers and Dolland was able to construct a lens capable of forming a colorless image of an object illuminated by white light. These " achromatic " lenses are now part of all microscopic outfits.

The essential function of the microscope is to make small objects visible to the human eye, but *definition,* that is, the clear indication of form and structure, is also essential, and the later work of improving the microscope is directed especially to securing this. It has been accomplished partly by improvements in lenses, but largely by modifications in the nature of the light and the method of applying it. The most simple modification is that of changing the direction of the beam that illuminates the object to be examined. The natural way, which was at first used, is to allow the beam to pass directly through the object, that is, perpendicular to it, or to fall upon the surface at a similar angle. By passing the ray obliquely, or concentrating it as a cone centering

---

* Abstract of a paper presented at a meeting of the Section of Physics and Chemistry held Thursday, October 27, 1921.

in the object, shadow effects are produced which are often very satisfactory.

The application of photography to microscopy has been of great service, as it not only permits of permanent record of the field, but as the photographic plate has a different sensitiveness to light than has the human eye, differences of structure will be brought out by this means that the unaided eye would overlook. The ordinary photographic emulsions are not sensitive to green, yellow or red light. By special methods this sensitiveness may be extended so that a strong light of any color will affect the plate. Using plates of wide range of sensitiveness, color screens can be

Section of dolerite × 30. White light.   Section of dolerite × 30. Red screen.

inserted by which excellent results are often secured. Another modification of light which has been of immense advantage in all fields of optics is polarization. The term is applied to modifications of light by which it becomes much more sensitive to structure so that differences wholly inappreciable to the unassisted eye are brought out clearly. These differences are often indicated by brilliant colors, so that the several parts of the object are not only clearly indicated but the color contrasts are striking and often beautiful.

Another direction in which the service of the microscope has been advanced is in the preparation of the object. Many methods for this purpose are employed. One of the most used is sectioning, that is, cutting the specimen into thin layers. In the case of

animal and vegetable structures this is comparatively easy, and has been employed from an early period, but mineral structures are more difficult to handle. Sorby, a British scientist, developed about the middle of the last century the method of grinding minerals so thin as to be transparent, and laid the foundation of the science of petrology, which has become of great importance in mineralogy and geology. In the case of metals no amount of cutting will render them transparent to ordinary light, but many important data have been obtained by examining flat surfaces before and after etching. A special department of industrial microscopy—metallography—has grown up by aid of the methods of which the minute structure of commercial metals and alloys are capable of elucidation.

The microscope has found extensive and useful application in medico-legal work. Its revelations are often surprising and sometimes border on the humorous, because of the results being so different from what was assumed. During the late war cases of admixture of powdered glass with food were occasionally alleged. No case in which such a charge was substantiated seems to have been established, but several investigators have reported the actual facts. In one case crystals of ammonium magnesium phosphate were found; in another, in which it was suspected that grape-jelly had been so adulterated, the analyst (Doctor LaWall) found that the substance was merely cream of tartar (acid potassium tartrate) in comparatively large crystals. The client, however, was firm in his opinion, and it was not until the analyst dissolved some of the material in hot water that he was convinced it was not glass.

Messrs. Zoller and Williams, of the United States Bureau of Agriculture, recently reported a case of " sandy " ice cream, which on microscopic examination was found to owe its grittiness to numerous crystals of milk sugar. Commercial white arsenic (arsenous acid), the common poison, is found in two forms, a glassy or porcelain-like mass and a gritty powder. The latter generally shows distinct crystals, visible under moderately high powers, the particular form being the regular octahedron, but much broken up. This form of arsenic will remain for many hours in the stomach without material modification so that the substance may be identified directly. In one case of criminal poisoning, the defence set up the theory that the dead person had been taking homœopathic triturations of arsenic, but the expert for the state

pointed out that the arsenic found in the stomach was distinctly crystalline, which proved that it had not been triturated. The prisoner was convicted and executed, and subsequently his attorney admitted the correctness of the inference, and the remainder of the arsenic, which had been bought for the poisoning, was given to the expert.

By making thin sections of fossils and coal much information may be obtained as to the origin of these materials. Coal shows vivid evidence of its vegetable origin, not only by the impressions of leaves and stems, that are visible to the naked eye, but on

Section of coal × 120. Showing vegetable cells.

magnification, the minute details of the cell structure and spores. Considerable advance has been made lately in the study of coal, by treatment with hydrofluoric acid, by which the mineral matter is in great part removed, and thus the remains of the vegetable structures made more evident.

The fossil tree-trunks in the petrified forests of Arizona have retained the vegetable structure through the silicification, even to very minute detail, and by the microscope it can be shown that they are cone-bearers, related to our pines and spruces. They show clearly the peculiar dotted cells, technically known as the " bordered pits " which are characteristic of that group of plants.

In the field of pathology and bacteriology the microscope has been of immense use. Its applicability has been materially increased by the use of cultures and staining systems. The inven-

tion of the solid culture medium, by Doctor Koch, has been one of the most important accessories in this work. Microörganisms can be cultivated in many liquids and on many surfaces, but the

Crystal of milk sugar × 100.
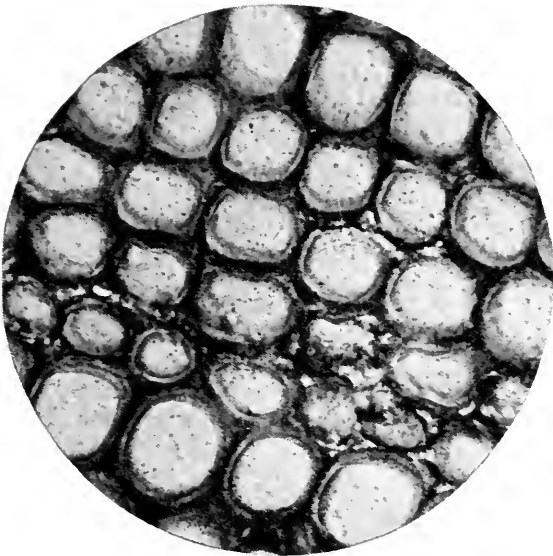
Tranverse section of petrified wood. Petrified Forest of Arizona × 120.

Section of petrified wood × 120. Showing "bordered pits" which indicate cone-bearing tree.

different species remain in intimate mixture and study of individual forms is impossible. By incorporating into the culture fluid a substance which is liquid when moderately warm, but solid at ordinary temperatures, the organisms can be cultivated separately. Gelatin and agar are usually employed, the latter being especially

applicable for cultures made at blood heat, as its jelly does not melt at that temperature. The procedure, in outline, is to prepare a sterile culture medium containing the jelly-forming substance, inoculate under proper precautions, spread it in a shallow dish, and cover it with a protecting lid. When cold the jelly sets, and the individual organisms multiply in their places, soon forming colonies so numerous that they are large enough to be seen by the naked eye. In growing, some organisms produce marked changes in the condition of the gelatin or agar. Some digest it partly, causing spots of liquid, others produce colors. One well-known and common organism produces a blood-red stain. From the colonies thus indicated, portions can be taken and separately cultivated, just as one can gather seeds from the mature plants of a garden.

Another great advance was made when the methods of staining bacteria and tissues were invented. Many of the coal-tar dyes have the property of adhering firmly to certain tissues and organisms, while other tissues and organisms, which show no difference to the eye, will not hold the dye. In this way objects may be made much more distinct. The germ of tuberculosis is capable of taking certain dyes firmly, while some associated organisms which closely resemble it in form will not retain these colors. By dyeing the material and then subjecting it to treatment with dilute acid, all organisms but the tubercle germ will lose their color, so that a marked contrast is obtained.

One of the latest applications of the microscope is its use in determining the index of refraction. This datum is the expression of the amount to which the ray of light is bent on passing from air into the mass of the substance under examination. The figure for the index is obtained by dividing the sine of the angle of incidence by that of the angle of refraction. In dealing with solids and liquids as compared with air the quotient is, of course, always greater than unity. Differentiation of both solid and liquid substances can be made rapidly and accurately by determinations of this index. In microscopic work, the method is largely applied in examining crystals.

In examining substances more or less transparent immersed in a liquid, the individual particles are seen to be surrounded by a series of bands either in monotone or in colors. The relative

extent of these bands depends on the difference between the refractive index of the substance and that of the liquid bathing it. If the objects examined are entirely homogeneous, without color, have the same refractive and dispersive powers, and also the same absorptive powers for light as the liquid, they will become invisible. All these conditions as coincident are not found in practice, so there is always some visibility. In practice the vanishing of the dark bands is the phenomenon that is used to aid in the examination. If, for instance, a crystal is examined successively in liquids of which the index of refraction is known, it is possible to determine that of the solid, by noting the liquid in which the dark bands are just eliminated.

By these means crystals of very small size can be identified and many interesting and valuable results have already been obtained. Dr. Edgar T. Wherry, of the United States Bureau of Chemistry, has for several years been devoting a great deal of attention to this phase of research and has made many determinations. One of the most interesting and valuable was in the detecting of the cause of mortality among bees in some parts of Pennsylvania. The honey on being examined was found to contain crystals of unusual form, and as the amount was very small resort was had to the determination of the index of refraction, by which the substance was identified as melezitose, a sugar that is of no nutritive value to the bee. This had been obtained probably by the bees collecting exudations on pine trees, during a period in which flowers were scarce. Doctor Wherry made also examinations of some high explosives which were of different colors as produced in different factories and found that the difference was due to enclosures in the crystals.

Efforts have been made of late to apply the refractive index to the differentiation of the common alkaloids. Some of these are powerful poisons, and as they are used in small amount the processes of analysis have to be very delicate. Many of the tests depend upon color produced by reagents, but in these the alkaloid is destroyed. The crystalline forms of the alkaloid itself or of its salts are sometimes fairly characteristic, but as a rule such method is only applicable to the pure substance. In toxicologic analysis the material is often difficult to obtain perfectly pure, and this complicates the work. Naturally the determination of the refrac-

tive index seems to be a possible method, but one difficulty has arisen, namely, to secure liquids which do not have a solvent action on the crystal. It is obvious that if the substance dissolves in the liquid bathing it, no accurate test can be made. Human ingenuity is, however, almost limitless, and it is reasonable to expect that some method will be found by which this useful datum will be made available for the toxicologist and pharmacologist in identifying these important substances.

British Developments in Nitrogen Fixation.—The *Chemical News* presents the following abstract of a report from the Ministry of Munitions. The synthetic ammonia factory at Billingham, designed to manufacture about 60,000 tons of ammonium nitrate annually for war purposes, was commenced by the Ministry of Munitions early in 1918, but at the time of the Armistice was only very little advanced. It has since been taken over from the Government by Messrs. Brunner, Mond and Company, Ltd., and is being re-designed to manufacture peace products, chiefly fertilizers. The subsidiary company they have promoted, Synthetic Ammonia and Nitrates, Ltd., will have a capital of £5,000,000, is at present concentrating upon designs for an initial plant to produce 25 tons of ammonia per day, or about 6000 to 7000 tons of nitrogen annually. Their works are, however, being laid out so that this small nucleus installation may be quickly enlarged to 100 tons per day and afterward to a maximum capacity of 300 tons per day, or about 80,000 tons of nitrogen annually. The original Government site of 260 acres is being increased to about 1000 acres in all, and two ship berths on the River Tees have been acquired. This increased accommodation has been found necessary in order to give ample room for the development of the whole scheme, which includes the manufacture of a number of by-products. There is also to be an oxidation plant of a capacity of 10,000 to 12,000 tons of nitric acid annually. A British company, Cumberland Coal Power and Chemicals, Ltd., has also been formed to erect works in England to operate the Claude process for the manufacture of synthetic ammonia. Information to hand states that a full-sized commercial ammonia unit, working at 1000 atmospheres, is now running satisfactorily in France, producing at the rate of 5 tons of ammonia per day. The British Cyanides Company is continuing at Birmingham its large-scale experiments on fixation of nitrogen by the barium process, employing fuel-heated furnaces. Though these experiments have been partially successful, final conclusions as to the ultimate possibilities of the process have not yet been reached. The works erected at Dagenham by the Nitrogen Products Company to manufacture ammonium nitrate during the war period from cyanamide by the Ostwald process are now closed. H. L.

ELECTROLYTIC CONCENTRATION OF AQUEOUS SOLUTIONS OF NITRIC ACID. I.*

BY

HENRY JERMAIN MAUDE CREIGHTON.

Department of Chemistry, Swarthmore College.
Member of the Institute.

THE nitric acid produced in the arc processes for the fixation of atmospheric nitrogen [1] usually has a concentration of 33 to 35 per cent. A dilute acid is also produced in its formation by the oxidation of ammonia,[2] while in the ordinary method of manufacture from Chili saltpetre a dilute acid (38° Bè. or less) is obtained from the final towers or tourilles of the condensing system. On account of the many uses for concentrated nitric acid, the problem of concentrating its dilute aqueous solutions is an important one and one which has received much attention. As is well known, dilute aqueous solutions of nitric acid can only be concentrated to about 68 per cent. HNO_3 by distillation at atmospheric pressure, due to the formation of a mixture of maximum boiling point; and by distillation with concentrated sulphuric acid aqueous solutions containing 68 per cent. nitric acid (mixture of maximum boiling point) can be concentrated to over 90 per cent.[3] Attempts have been made to concentrate dilute nitric acid electrolytically,[4] but, as Molinari points out,[5] these have not yielded practical results.

When an aqueous solution of nitric acid is electrolyzed between platinum electrodes, the NO_3-ions and the H-ions migrate, respectively, to the anode and the cathode and are there discharged, the resulting NO_3-radicals reacting with the water of the solution in accordance with the equation:

$$2NO_3 + H_2O = 2HNO_3 + O.$$

---

* Communicated by Professor Creighton.

[1] Creighton, H. J. M., This Journal, **187**, 379–399 (1919).

[2] Creighton, H. J. M., *Ibid.,* **187**, 705–714 (1919).

[3] Cf. Creighton, H. J. M., and J. H. Githens, *ibid.,* **179**, 161 (1915); Creighton, H. J. M., and H. G. Smith, *ibid.,* **180**, 703 (1915).

[4] German Patent, No. 180,052; English Patent, No. 18,603 of 1906.

[5] "General and Industrial Chemistry (Inorganic)," p. 396, second edition. P. Blakiston's Son and Co., Philadelphia, 1920.

This oxygen and the hydrogen set free at the cathode escape from the electrolyte in the proportions in which they are present in water. The net result of electrolysis is, therefore, the decomposition of some of the water and a consequent increase in the concentration of the nitric acid which remains in the solution. If, however, the dilute nitric acid is electrolyzed in a cell which is divided into an anodic and cathodic section by means of a porous diaphragm and F faradays of electricity are passed through the electrolyte, the following changes occur: At the cathode F gram-ions of hydrogen discharge and escape from the solution, but, since the transport number of the NO_3-ion in nitric acid is *ca.* 0.15, this loss is partially compensated by migration into the cathodic section of 0.85 F gram-ions of hydrogen from the anodic section of the cell. At the same time 0.15 F gram-ions of NO_3 pass from the cathodic to the anodic section. There occurs, therefore, **during** the passage of the current, a loss of 0.15 F gram-molecules of nitric acid in the cathodic section. At the anode F gram-ions of NO_3 discharge. The nitrate radicals which result do not leave the solution, but react with the water to form F gram-ions of hydrogen, F gram-ions of NO_3 and 0.5 F gram-atoms of oxygen, the latter escaping from the electrolyte. Since the anodic section gains F gram-ions of hydrogen through the NO_3-ion discharge and 0.15 F gram-ions of NO_3 by migration from the cathodic section, and loses 0.85 F gram-ions of hydrogen by migration to the cathodic section, there results a gain of 0.15 F gram-molecules of nitric acid in the anolyte. Thus, the concentration of the acid in the anolyte is increased at the expense of that in the catholyte, the gain in the former being equal to the loss in the latter.

Some of the hydrogen set free in the nascent state at the cathode reduces part of the nitric acid in the vicinity of the electrode, say through the stages:

$$HNO_3 \longrightarrow NO_2 \longrightarrow HNO_2 \longrightarrow NO \longrightarrow H_2N.OH \longrightarrow NH_3.$$
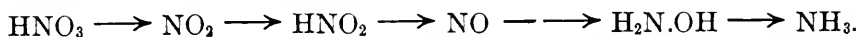
The nature of the reduction product formed depends on the temperature, current-density, concentration of the acid and the material of the cathode. As early as 1839 Schönbein [6] observed that nitric acid was reduced at the cathode when the acid was concentrated, and that current-density played a rôle, while later Brester [7]

[6] *Pogg. Ann.,* **47,** 563 (1839).
[7] *Archiv. de Genève* (N. S.), **28,** 60 (1866).

found that during the electrolysis of dilute nitric acid ammonia was formed at the cathode.   More recently, Ihle[8] has shown that, for a given concentration of nitric acid, ammonia and hydroxylamine are formed at a smooth platinum cathode when the current-density is above a definite value, and that this value increases with the concentration of the acid.   Thus, at different acid concentrations the minimum current-density at which ammonia is formed is:

| Concentration of nitric acid.. | 14.67 | 28.73 | 43.34 | 85.37 per cent. |
| Current-density .... | 0.15 | 1.122 | 5.64 | 860.0 amp /dm.^{2} |

In studying the influence of the material of the cathode on the nature of the reduction product, Tafel[9] has found that while nitric acid (in the presence of 50 per cent. sulphuric acid) is reduced only to hydroxylamine at a mercury or well-amalgamated cathode, it is reduced at a copper cathode to ammonia; with a lead cathode 40 per cent. of the nitric acid is reduced to hydroxylamine, and with a platinum cathode there is no reduction when the acid is very dilute.   Electrolysis of 40 per cent. nitric acid containing a small quantity of oxides of nitrogen has been found to yield pure nitric oxide at a carbon, graphite, gold or platinum cathode.[10]

It is evident from the foregoing that during electrolysis in a diaphragm cell not only will the concentration of the nitric acid in the catholyte be decreased by loss of hydrogen and migration of NO_3-ions to the anolyte, but also by partial conversion of the acid to the oxides of nitrogen (which escape from the solution), ammonia, etc.   If, however, electrolysis is carried out under such conditions that the acid is reduced to the oxides of nitrogen, loss of the acid by reduction may be overcome, partially at least, by leading the gases formed in the cathode section into the anolyte where, in the presence of water and nascent oxygen, the oxides of nitrogen are converted to nitric acid, thus further concentrating the acid in the anodic section of the cell.

Some years ago the writer carried out a few experiments on concentrating aqueous solutions of nitric acid by electrolytic means.   This work was unavoidably interrupted but has recently been resumed.   In this paper a brief account of the results of these preliminary experiments is given.

A few experiments were first carried out in which 70–71 per

[8] Z. physik. Chem., 19, 572 (1895).

[9] Z. anorg. Chem., 31, 289 (1902).

[10] Meister, Lucius and Brüning, English Patent, No. 10,522 of 1911.

cent. nitric acid was electrolyzed in a cell without a diaphragm between the following electrodes: (1) A carbon anode and cathode, (2) a smooth platinum anode and a lead cathode, and (3) a smooth platinum anode and a carbon cathode. With the first combination of electrodes it was found that with an anodic current-density of 4–5 amp./dm.^{2} fragments of the anode began to break off with a loud cracking sound within a few seconds after the current had been turned on. In one instance a large piece of the anode was shot off with such violence that it cracked the glass beaker containing the electrolyte. After electrolysis had proceeded for a short time the anode had disintegrated to such an extent as to render it useless.[11] The cathode did not undergo this disintegration. It was found on repeating the electrolysis with the second combination of electrodes, using a cathodic current-density of 5–8 amp./dm.^{2}, that the cathode gradually lost its brightness and malleability and was transformed into a soft, powdery, allotropic modification of lead.[12] Accordingly, in the concentration experiments which follow platinum electrodes were employed, although a carbon cathode could have been used with a platinum anode.

The electrolysis cell used for the concentration experiments consisted of a glass cylinder in which was placed a porous, unglazed, porcelain cylinder closed at the bottom. The former contained the anolyte and the latter the catholyte. The top of the porous cylinder was closed by a stopper through which passed the cathode. A glass tube also passed through this stopper and carried the nitrous gases and hydrogen evolved in the cathodic section into the anolyte immediately below the anode. The stopper contained a third opening through which electrolyte could be removed or introduced. The acid used for the anolyte and catholyte was c. p. nitric acid (sp. g. = 1.42) containing about 71 per cent. HNO_3. The electrolyses were carried out in an open room in winter weather at a temperature of from 5 to 10° C. The increase in the concentration of nitric acid in the anolyte (or the decrease in concentration in the catholyte) was followed by removing 10 cc. of the electrolyte, diluting to 1000 cc. and neutralizing 10 cc. of this dilute solution with a standard solution of barium hydroxide.

---

[11] This phenomenon of the disintegration of carbon anodes in nitric acid is being studied further.

[12] Creighton, H. J. M., *Jour. Amer. Chem. Soc.*, **37**, 2064 (1915).

In all experiments the final concentration of the acid was determined by analyzing a known weight of the anolyte.

In Table I are given the results of a concentration experiment

TABLE I.

Time Hours	Current- strength Amperes	Potential difference Volts	Quantity of electricity consumed Amp.-hrs.	Energy Consumed Kw.-hrs.	Concentration of HNO₃ in	
					Anolyte %	Catholyte %
0	6	3.5	0	0	71.70	71.70
2	6	3.5	12	0.042	74.35	....
4	6	3.5	24	0.084	76.44	....
6	6	3.5	36	0.126	78.88	....
8	6	3.5	48	0.168	81.35	....
11*	6	3.5	66	0.231	84.00	50.36
11	2	2.0	66	0.231	84.00	50.36
22	2	2.0	88	0.275	....	....
22	6	3.5	88	0.275	....	....
25	6	3.5	106	0.338	88.40	....
27	6	3.5	118	0.380	92.22	....
34	6	3.5	160	0.507	94.40	14.04

* The color of the catholyte was blue-green.

TABLE II.

Time Hours	Current- strength Amperes	Potential difference Volts	Quantity of electricity consumed Amp.-hrs.	Energy consumed Kw.-hrs.	Concentration of HNO₃ in anolyte %
0	7	3.4	0	0	71.4
4	7	3.4	28	0.0952	73.5
8	7	3.4	56	0.1904	76.7
12	7	3.4	84	0.2856	77.2
21*	7	3.4	147	0.4998	80.6
25	7	3.4	175	0.5950	83.0
29	7	3.4	203	0.6902	84.5
29	6	3.0	203	0.6902	84.5
35†	6	3.0	239	0.7982	...
46	6	3.0	305	0.9962	90.1
46	8	4.0	305	0.9962	90.1
48	8	4.5	321	1.0642	...
49	8	5.5	329	1.1042	...
50	8	6.0	337	1.1502	...
51	8	6.5	345	1.2002	92.2

*250 cc. catholyte removed and 250 cc. 71.4% HNO₃ added to cathode section.
†200 cc. catholyte removed and 200 cc. 71.4% HNO₃ added to cathodic section.

in which the volumes of anolyte and catholyte used were, respectively, 250 cc. and 150 cc. of 71.7 per cent. nitric acid. In a second experiment, the results of which are recorded in Table II,

the volume of anolyte was 975 cc. (1385 grams) and the volume of catholyte was 550 cc. (780 grams). In this experiment 345 ampere-hours of current were passed through the cell and the concentration of the anolyte raised from 71.4 to 92.2 per cent. HNO_3 ($d_4^{15°} = 1.4987$). The weight of the anolyte at the end of the experiment was 1210 grams. That this weight was not greater was due to losses by evaporation, to the removal during the experiment of 150 cc. for titration, and probably to loss by diffusion into the cathodic section. In another experiment an attempt was made to increase further the concentration of the 92.2 per cent. acid obtained in the preceding experiment. Three hundred grams of the 92.2 per cent. acid were placed in the anodic section and 285 grams of 71.4 per cent. acid were placed in the cathodic section of a small concentrating cell. As it was desired to obtain as pure an acid as possible, the nitrous gases formed in the cathodic section were not led into the anolyte and the temperature of the electrolyte was not allowed to rise above 8° C. The acid was electrolyzed for seven hours, during which time 48 ampere-hours of current were passed through the cell and 0.300 kw.-hr. of energy consumed. At the conclusion of electrolysis there were 350 grams of anolyte containing 99.65 per cent. HNO_3 ($d_4^{15°} = 1.5193$). On being removed from the cell at the conclusion of electrolysis this acid was almost colorless; but after standing for twenty-four hours in a room at ordinary temperature it became lemon yellow in color.

In each of the foregoing experiments the porous cylinder underwent considerable disintegration and could not be used for a second experiment. This difficulty can probably be overcome, however, by using an aluminum cylinder, since it has been found that a cylinder of this material undergoes but little change in weight on being immersed in 70 per cent. nitric acid for six weeks.

In order to determine to what extent "spent acid" (i.e., a mixture of nitric and sulphuric acids diluted and partially deprived of the former acid by use in nitrating organic substances, e.g., glycerine) could be concentrated electrolytically, a spent acid containing 70.03 per cent. H_2SO_4, 10.06 per cent. HNO_3 and 19.91 per cent. H_2O was electrolyzed, the gases evolved in the cathodic section of the electrolysis cell being led into the anolyte immediately below the anode. Four hundred and fifty-five grams of the spent acid were placed in the anodic section of the cell and 370 grams in

the cathodic section.   The acid was electrolyzed for ten hours with a current of eight amperes, the mean potential difference being 6.75 volts.   At the conclusion of electrolysis the weight of anolyte was 440 grams.   The anolyte was analyzed and found to contain 74.4 per cent. H_2SO_4, 21.32 per cent. HNO_3 and 4.28 per cent. H_2O.

SUMMARY.

1. A number of preliminary experiments on concentrating aqueous solutions of nitric acid by electrolytic means have been carried out.

2. The concentration of nitric acid has been increased from 71 to over 99 per cent. HNO_3 by electrolysis in a diaphragm cell.

3. The concentrations of nitric and sulphuric acids in " spent acid " have been materially increased and the amount of water decreased by electrolysis.

DEPARTMENT OF CHEMISTRY,
 SWARTHMORE COLLEGE,
  SWARTHMORE, PENNA.,
   December 10, 1921.

An Acoustical Galvanometer for the Measurement of Small Alternating Currents.   F. R. WATSON and L. B. HAM.   (*Phys. Rev.,* September, 1921.)—Ordinarily the word galvanometer calls up the image of a moving part actuated by the action of one magnetic field upon another.   In the acoustical galvanometer there is one magnetic field, because there is a current of electricity, but there is not a second one.   The alternating current to be measured passes through a Western Electric No. 117W loud-speaking telephone receiver.   The plate of this is set in vibration and sound waves are produced in an enclosed mass of air.   This closed chamber consists of two cylinders joined by a tube.   The receiver forms the end of one cylinder and the other is closed by a plate of glass.   Within this double resonator standing waves are formed.   In the connecting tube is suspended by a quartz thread a Rayleigh disc, a microscope cover glass in fact, with its plane at an angle to the axis of the tube.   When standing waves develop this disc turns through an angle.   A ray of light enters through the glass end, is reflected from the suspended disc and is received upon a scale.   When the disc turns this reflected ray is deviated.   When the sound wave had a frequency of 510 vibrations per sec., 5.7×10^{-8} amperes produced a deflection of one mm. on a scale one metre distant from the deflected disc.   The sensitivity varies with the frequency.

The suggestion is made that the instrument can be made to measure larger alternating currents. It may be used to replace the ear in telephone research and in psychological work where an objective measure is to be correlated with subjective impressions through the ear.

G. F. S.

The Distinction Between Intrinsic and Spurious Contact E. M. F. S. and the Question of the Absorption of Radiation by Metals in Quanta. R. A. MILLIKAN. (*Phys. Rev.,* Sept., 1921.)— The wide-reaching conclusions so clearly presented by Richardson in his Vice-presidential address at the 1921 B. A. A. S. to the effect that the data of the photo-electric effect demonstrate the existence of a real contact difference of potential are still further buttressed by this present paper which summarizes a long series of researches. " The accompanying experiments, then, taken in connection with those of Page and those of Kadesch and Hennings, show in the most beautiful quantitative way that all clean metals possess intrinsic contact e. m. f. s." " Thus the century-old dispute as to the reality of intrinsic contact e. m. f. s. appears to be quite definitely settled by experiments of this type." " It it to emphasize, too, that the result is a purely experimental one which is quite independent of any theory, although it is beautifully in accord with the theory of electron atmospheres."

G. F. S.

Some New Experiments on Gravitation. CHARLES F. BRUSH. (*Phys. Rev.,* August, 1921.)—At the meeting of the American Physical Society in April, 1921, the results of certain experiments in relation to gravitation were presented, as follows:

" 1. Gravitational Attractions of a Kg. each of Bismuth and of Zinc for a Small Nearby Ball of Silver Are Not the Same.

" 2. A Gravity Pendulum with a Bismuth Bob Has a Shorter Period than a Similar Pendulum of Exactly the Same Oscillation Length Having a Zinc Bob.

" 3. A Torsion Pendulum Having Equal Horizontal Arms Loaded with Equal Weights of Bismuth Has a Shorter Period than when the Arms Are Loaded with Equal Weights of Zinc of the Same Weight as the Bismuth Loads; The Radii of Gyration Being Exactly the Same in Both Cases."

These conclusions are in direct opposition to the accepted relation of mass to weight and are in contradiction to the results of careful experiments made by others. Should they, upon repetition, prove to be justified they will render necessary a vast amount of scientific reconstruction.

G. F. S.

PRINTING TELEGRAPH BY RADIO.*

BY

R. A. HEISING, E.E., M.S.

Research Laboratory, American Telephone and Telegraph Company and
the Western Electric Company, Inc.

In the *Annales des Postes, Telegraphes et Telephones* for June, 1921, M. M. Henri Abraham and Rene Planiol describe their experiments with a printing telegraph operated by radio, and mention the fact that similar experiments had been made in the United States. The tests in this country were made during the latter part of 1919 by engineers of the American Telephone and Telegraph Company and the Western Electric Company, Inc., between New York City and Cliffwood, New Jersey. The work was mainly the adaptation of present-day radio to the commercial multiplex printing telegraph,[1] or in other words, the substitution of a radio transmission link for the customary wire transmission line.

In these experiments a radio transmitter was installed at the Western Electric Company's building at 463 West Street, and a receiver at their experimental station at Cliffwood, New Jersey, a distance of twenty-five miles. The printing telegraph, both transmitting and recording ends, was located in the printing telegraph laboratory in the same building as the radio transmitter, but separate from it. The usual outgoing signals from the printer were transmitted by wire to the radio room, where, by means of a relay controlling the radio transmitter, they were converted into radio signals. The received signals at Cliffwood actuated a polar relay and converted the radio signals back to wire signals which were relayed by wire back to the printer laboratory in New York. The transmitting and printing of the telegraphic messages were thus done in the same room but with a combined radio and wire transmission circuit between.

RADIO TRANSMITTER.

The radio transmitter used in these experiments was of the audion class. It contained six tubes of the type known as fifty-watt tubes. One was used in an oscillator circuit to maintain the

---

frequency constant and the other five were in parallel as amplifiers. The amplifier tubes delivered their power directly into the antenna. A plate potential of 750 volts was used and three amperes at 450 metres was secured in the antenna.

The control of the transmitter was by means of a Rainey polar relay. This relay operated on the grid circuit of the tubes, applying a negative potential to stop oscillations and removing it to start them. The signals from the printing distributor are in the form of positive and negative pulses. The relay controlled the radio transmitter in such a manner that the positive impulses put

FIG. 1.
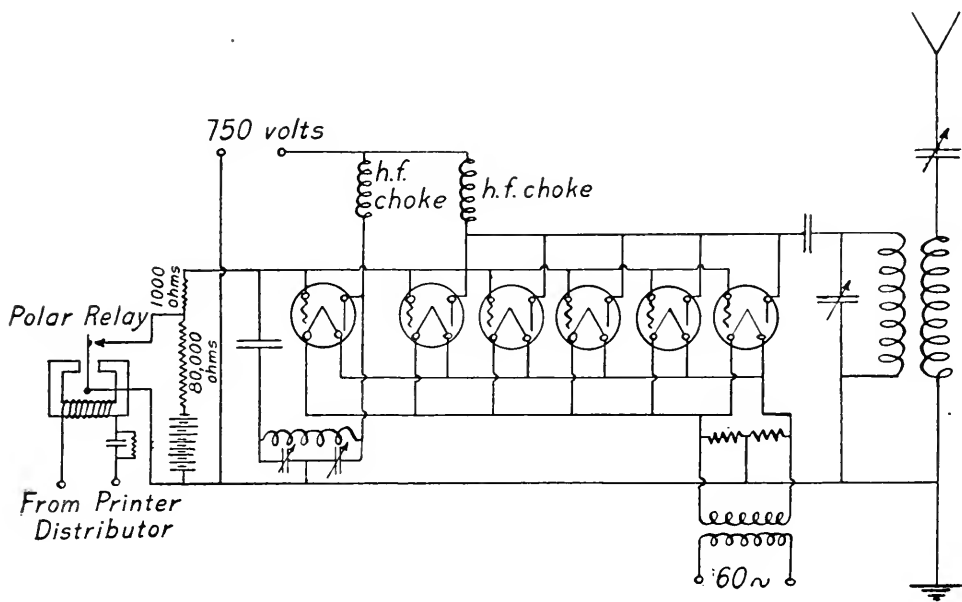
Printing telegraph transmitter.

sustained power into the antenna and the negative impulses removed it. The radio transmitter and control circuits are shown in Fig. 1.

RADIO RECEIVER.

The receiving circuit with repeating relay is shown in Fig. 2. To eliminate interference, a highly selective circuit was necessary. The principal interference in the neighborhood of New York on such waves as 450 metres is not static or strays, but spark stations. Static and strays at times are bad, but the interference from spark stations is quite continuous and was at first a source of trouble. The sharpness of the receiving circuit as finally constructed was such that very few errors in transmission could be attributed to

interference.   A curve indicating the high selectivity is shown in Fig. 3.   The strength of the received signal at Cliffwood was such that connecting a detector directly to the antenna gave about one microampere rectified plate current.   Sufficient amplification was used to give a maximum of 20 mil-amperes through the relay. Since the relay could be adjusted to give satisfactory operation with two mil-amperes, the 20 mil-amperes secured gave excellent operation.

FIG. 2.
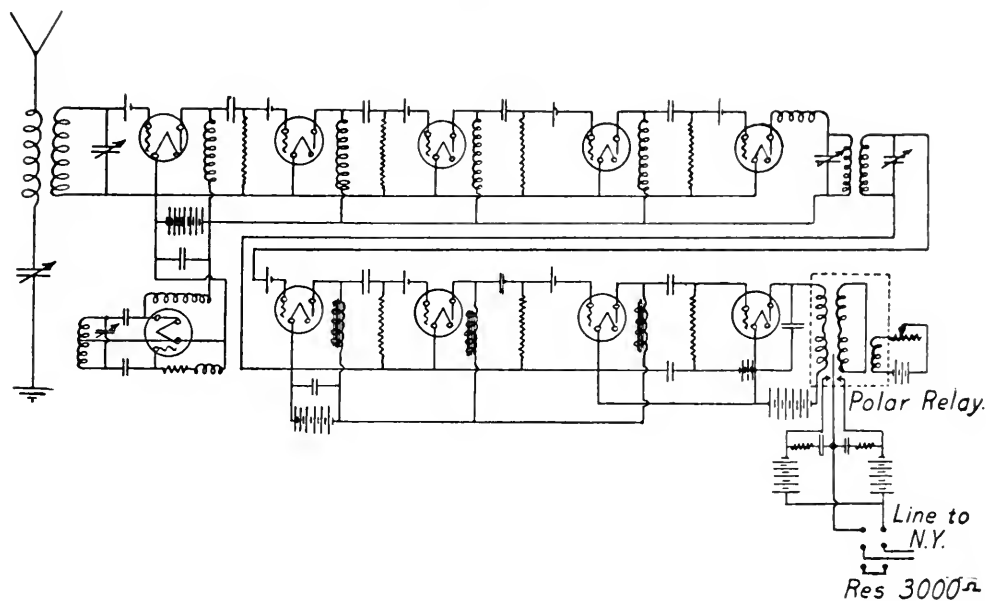
Radio receiving set for printing telegraph.

RESULTS.

Fig. 4 shows an oscillogram of the behavior during the first operation on November 20th.   This represents a test signal being sent at the rate of forty-five words (270 characters) per minute per channel.   The upper curve is that of the signal arriving in the radio room from the printer sending distributor.   It is in the form of positive and negative impulses.   The middle curve is rectified antenna current at the radio transmitter to show the character of the conversion into a radio signal.   The bottom curve is the signal received back from Cliffwood by wire.   A slight lag is observed in this signal.   It is caused partly by the receiving set relay but largely by the receiving set radio circuit.

The printer was operated first on November 20, 1919.   No trouble was encountered in keeping the mechanism synchronized as the signals from around the circuit were much better than those

from many wire circuits. On November 25th two channels of
the four were operated for about an hour, 29,000 characters were

FIG. 3.
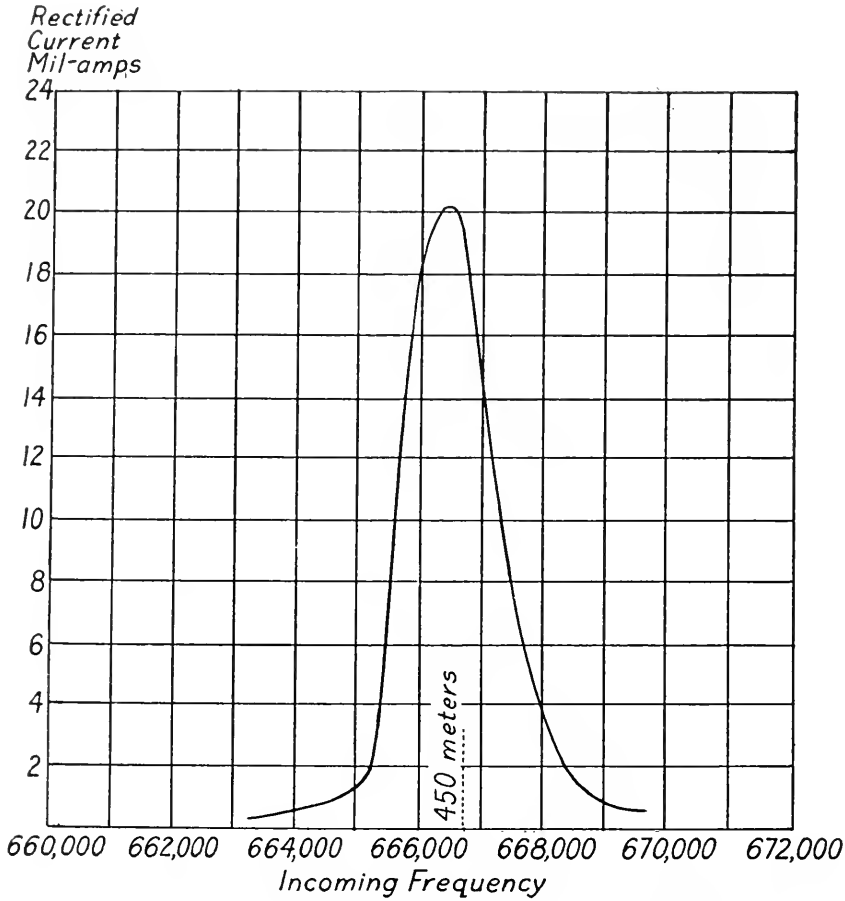
Resonance curve of printing telegraph receiving set, Cliffwood, N. J.

FIG. 4.
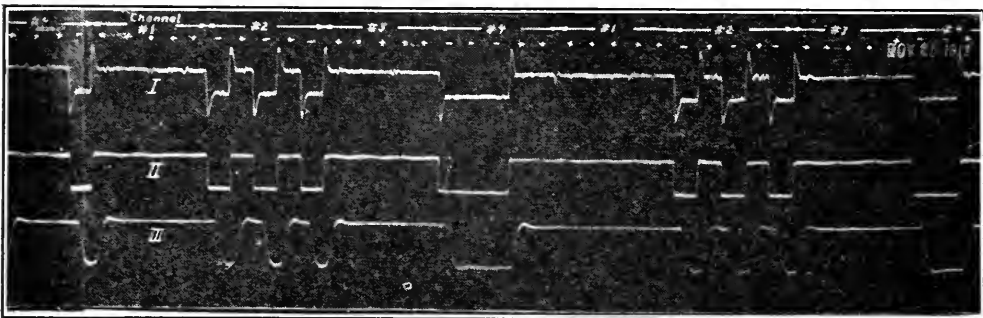
transmitted with fourteen possible radio mistakes. This latter
figure is thought to be too large because the errors due to wearing
of the tape from continual use numbered thirty-five. The four-

teen errors were those which could not be conclusively attributed to the condition of the tape.

The speed with which the printer could be operated was in no way limited by the radio. The speed used in the tests—180 words per minute, or 10,800 words per hour on all four channels together—happened to be the rate at which other experimental work in the printer laboratory was being done. The oscillograms showed a character of signal that indicated that the printer could have been operated at its highest rated speed of 12,720 words per hour without trouble.

The short line or start-stop printer has also been operated over this circuit. It is worked with less difficulty due to the increased length of the signal impulses.

These tests were witnessed by a number of persons. They have been repeated on several occasions since with similar success.

Protecting Merchant Ships from Submarines.—The menace of the submarine was made evident during the war by many a loss and by much sacrifice of life. The British fleet cleared the sea of German and Austrian cruisers almost entirely, but for a long while the submarine continued its work. The problem of preventing future action is a question of great importance, and efforts have been made at the Washington conference to secure some declaration limiting the use of these insidious enemies of ocean travel. In a paper before the North-East Coast Institution of Engineers and Ship-Builders, Sir E. H. T. D'Eyncourt details some of the expedients employed or suggested for overcoming the submarine warfare that Germany conducted, especially against British commerce. It is known that at one time the sinkings were very frequent, and the total loss of British merchant vessels and their cargoes was enormous. Many suggestions were made, of course, a large proportion of which were by persons who had no practical knowledge of conditions and were, therefore, not heeded. Some plans were not carried out because of the time required for the construction. One of the plans that was tried to a limited extent, and which seems to have been efficient, was to construct an outside shell on each side of the ship. This was called a " bulge." It was not considered profitable to attach it to small ships, but with large ones it was practicable. A ship so protected was attacked by a submarine in the Mediterranean in June, 1917. The torpedo hit the bulge full amidships; the opposite compartment was flooded to right the vessel, which returned to port and was quickly repaired. One striking feature was that the original thin hull of the ship was not damaged. Later in 1917, and in 1918, ships thus protected were hit and escaped.

The experience of the war showed that speed is a material pro-

tection against submarines. Very few fast vessels were seriously injured. It seems that if these two methods, bulge protection and high speed, could have been applied early in the war, the results of the German submarine campaign would have been much less serious to the allies.

The British authorities did not take kindly to the proposition to build the protected ships, nor to the building of large wheat-carriers, plans for which were sketched by the engineers.

The following is a brief statement of the protected vessel, the type being a cargo carrier and tanker:

Length, overall	500	feet.
Length, between perpendiculars	480	feet.
Breadth, extreme over bulges	72	feet.
Depth to upper deck	34	feet.
Draught	27	feet.
Corresponding displacement	20,000	tons.
Deadweight	15,000	tons.
I.H.P. of twin screw machinery	6,000	tons.
Maximum speed	13½	knots.

The design provided for the vessel to be protected for a length of about 300 feet amidships (*i.e.*, 60 per cent. of the total length) by bulge protection of such width that the hull proper would be about 11 feet (on the average) from the seat of a possible underwater explosion. The bulge would be divided by a longitudinal bulkhead into two compartments, the outer one being empty and the inner one containing water (on outward voyages) or oil (on homeward voyages). The vessel could then carry a large addition to her cargo of oil on homeward voyages.

The profile of the vessel was arranged to be practically symmetrical about amidships so that the "double-ended" appearance thereby obtained would render attack by submarine difficult.

H. L.

Tuolumne River and Canyon. (*U. S. Geological Survey Press Bulletin, No. 481.*)—Tuolumne River rises in a group of glacial lakes on or near the Sierra divide in California. The river flows through beautiful upland meadows in its upper part and then through a canyon, nearly 80 miles long, which it has cut in solid granite. For a distance of about 25 miles, according to the Geological Survey, the upper part of this canyon is 3000 to 4000 feet deep and is known as the Grand Canyon of the Tuolumne. At the lower end of this canyon lies Hetch Hetchy Valley, which is smaller than the Yosemite Valley but resembles it very much in every other way. The river finally passes through its lower canyon into the San Joaquin Valley.

NOTES FROM THE U. S. BUREAU OF STANDARDS.*

COLOR SENSITIVE PHOTOGRAPHIC PLATES AND METHODS OF SENSITIZING BY BATHING.[1]

By F. M. Walters, Jr., and Raymond Davis.

[ABSTRACT.]

ORDINARY plates which are sensitive to the blue, violet and ultra-violet may be made sensitive to other colors by the use of certain dyes. These may be incorporated in the emulsion, or the dry plates may be made sensitive by bathing in dilute solutions of the dyes.

This investigation was undertaken to study some of the conditions to be observed in the use of certain dyes for making ordinary plates color sensitive by bathing.

Pinacyanol (a red sensitizer) gives good results in dilute alcoholic solutions when used with ammonia, but plates bathed in water and stock solution keep much better and are almost as sensitive, provided they are thoroughly washed before sentitizing. This is because the soluble salts contained in the emulsion prevent the sensitizing action by flocculating the dye.

Wash or soak the plate in water for five minutes, and bathe for two minutes in the following bath at 18° C.

Water .... 100 parts
Pinacyanol (stock solution 1 to 1000).. 4 "

Rinse the plate in ethyl alcohol for three or four minutes and dry as rapidly as possible.

Stock solutions consist of 1 part dye to 1000 parts ethyl alcohol.

Films are best sensitized in a bath containing water, alcohol, ammonia and stock solution as follows. Bathe for four minutes in

Water .... 65 parts
Ethyl alcohol 95 per cent. .... 35 "
Pinacyanol (stock solution 1 to 1000).. 4 "
Ammonia 28 per cent. .... 2 "

Rinse in alcohol for three or four minutes and dry rapidly.

Dicyanin (used to sensitize for infra-red light) gives a much

---

* Communicated by the Director.
[1] Scientific Paper No. 422.

greater sensitiveness and extends farther into the infra-red when used in a dilute alcoholic solution with ammonia than when used with water alone.

Water .... 65 parts
Ethyl alcohol 95 per cent. .... 35 "
Dicyanin (stock solution 1 to 1000).... 4 "
Ammonia 28 per cent. .... 4 "

Rinse in alcohol for three or four minutes and dry rapidly.

The modern orthochromatic (green, yellow, and orange) sensitizers, pinachrome, pinaverdol, orthochrome T, and homocol are much less sensitive to the action of soluble salts contained in the emulsion than are pinacyanol and dicyanin. Ammonia may be added to a sensitizing bath of water and stock solution, but does not increase the sensitizing action appreciably except in the case of homocol.

Certain brands of orthochromatic plates were found to be superior to plates bathed with erythrosin (Kahlbaum's) but no commercial panchromatic plate compared favorably with pinacyanol bathed plates.

It was found that washing commercial panchromatic plates had a favorable action on the color sensitiveness. While the effect of water is not so marked as that of dilute ammonia, the increase in fog which accompanies the use of ammonia is largely avoided.

Five minutes' washing or soaking in water is sufficient. The plates should be dried rapidly, an alcohol rinse will assist materially.

OPERATION OF THE MODULATOR TUBE IN RADIO TELEPHONE SETS.[2]

By E. S. Purington.

[ABSTRACT.]

In radio telephone transmitter circuits using electron tubes the radiated power is caused to vary at speech frequencies usually by one of the three following methods: First, by variable absorption of the output power of a radio generator, as by a microphone in the antenna circuit; or second, by varying at speech frequencies the operating grid voltage of a radio generator, as in grid modulation; or third, by varying at speech frequencies the input plate voltage of a radio generator, as in plate modulation. The third method

[2] Scientific Paper No. 423.

is used in practically all commercial and military types of apparatus. It is superior to the others with respect to the intensity of signal conveyed for a given total input power, and with respect to inherent reliability and tone quality. This paper deals with phenomena in transmitters of this third type.

Three orders of current occur in the transmitter networks—direct, audio or speech frequency, and radio frequency. For convenience the network may be analysed into four parts—the direct power supply, the modulator unit, the generator unit, the radiator unit. The modulator receives direct power from the supply unit, produces speech frequency power which it delivers together with direct power to the generator unit. The generator in consequence produces modulated radio frequency power, which it delivers to the radiator. Devices are included in the generator unit to prevent radio power working back into the modulator, and similarly in the modulator to prevent speech power working back to the direct power supply.

Important curves for the generator are obtained by determining how the output radio current and how the input plate current depended upon the input plate voltage. The first indicates the modulated wave form which results from any specified speech variation in the input voltage. The second indicates the essential nature of the load which the generator imposes upon the modulator unit. The curves usually approximate straight lines, with however a falling off from linearity at high voltages. The plate current-plate voltage characteristic over any range of operation defines a resistance R_b which symbolizes the useful resistance load imposed upon the modulator. The modulator unit then consists of a tube and its load in parallel, the two being supplied from the direct power source through a common line impedance, an audio-frequency choke coil. The modulator tube operates as a periodic amplifier of speech currents, the output corresponding to the voltage impressed on its grid by the speech transformer.

The load on a tube acting as an amplifier or a generator may be expressed in terms of wave forms of plate voltage and plate space currents. For each frequency present, the numerical value of the load impedance is the ratio of the alternating voltage to the alternating space current, and the phase angle of the load is given by the departure from exact phase opposition. For a phase angle numerically exceeding ninety electrical degrees, the tube is a con-

sumer rather than a producer of power. Three kinds of phenomena prevent the true load impedance upon the modulator tube being derivable from the characteristics of the generator unit, as symbolized by the resistance R_b. First, the audio choke coil is of finite impedance resulting in an inductive component to the total load. Such an effect is not serious provided the choke coil impedance is two or three times the resistance R_b. Second, the audio impedance of condensers and inductances, especially those which operate as valves to prevent flow of radio energy into the modulator, may cause disturbing effects upon the load. Third, a distortion of wave forms corresponding to a capacity load results from the necessity of the generator producing power not only to overcome resistance losses, but also to vary the electromagnetic energy associated with the radiator circuit.

The value of a radio telephone transmitter as a conveyor of signals is measured not by the power it can deliver to the radiator, but rather by the variations of power during speech. Since the variations of output power depend upon the power of the modulator tubes, it is desirable to use modulators sufficiently powerful to modulate up to the point of distortion. Usually optimum results are obtained when the total power rating of the modulators equals the power rating of the oscillators. Under these conditions, the load impedance on the modulators due to the characteristics of the generator unit becomes one into which the modulators are capable of operating with high electrical efficiency.

RECOMMENDED SPECIFICATION FOR WATER RESISTING SPAR VARNISH.[3]

THIS specification was prepared under the auspices of the Bureau of Standards by the U. S. Interdepartmental Committee on Paint Specification Standardization, September 12, 1921. The committee consisted of representatives of the War, Navy, Agriculture, Interior, Post Office, Treasury, and Commerce Departments, the Panama Canal, the U. S. Shipping Board, and the Educational Bureau of the Paint Manufacturers' Association of the United States. The revision is largely based upon criticism of the first edition made by certain varnish manufacturers' clubs.

---

[3] Circular No. 103, 2nd edition.

The committee's draft was submitted to numerous representatives of the varnish industry, and careful consideration was given to their suggestions.

The specification gives the general requirements and detailed methods of sampling and testing, as well as basis of purchase. The general requirements are:

The varnish shall be suitable for use on both outside and inside surfaces of vessels, buildings, etc., and must be resistant to air, light and water. The manufacturer is given wide latitude in the selection of raw materials and processes of manufacture, so that he may produce a varnish of the highest quality. It must meet the following requirements:

Appearance.—Clear and transparent.

Color.—Not darker than a solution of 3 g. of potassium dichromate in 100 c.c. of pure sulphuric acid, specific gravity 1.84.

Flash Point (closed cup).—Not below 30° C. (85° F.).

Non-volatile Matter.—Not less than 40 per cent. by weight.

Set by Touch.—In not more than 5 hours.

Dry Hard and Tough.—In not more than 24 hours.

Working Properties.—Varnish must have good brushing, flowing, covering, and leveling properties.

Safety of Working.—Varnish must pass the draft test.

Water Resistance.—Dried film must withstand cold water for 18 hours and boiling water for 15 minutes without whitening or dulling.

Toughness.—Varnish must pass a 50 per cent. Kauri reduction test at 24° C. (75° F.).

RECOMMENDED SPECIFICATION FOR INTERIOR VARNISH.[*]

This specification was prepared under the auspices of the Bureau of Standards by the U. S. Interdepartmental Committee on Paint Specification Standardization, September 12, 1921. The committee consisted of representatives of the War, Navy, Agriculture, Interior, Post Office, Treasury and Commerce Departments, the Panama Canal, the U. S. Shipping Board, and the Educational Bureau of the Paint Manufacturers' Association of the United States. The committee's draft was submitted to numerous repre-

---

[*] Circular No. 117.

sentatives of the varnish industry, and careful consideration was given to their suggestions.

The specifications give the general requirements and detailed methods of sampling and testing, as well as basis of purchase. The general requirements are:

The varnish shall be suitable for general interior use, including both rubbed and unrubbed finish, exclusive of floors. It must be capable of easy application with a brush in the ordinary manner according to the rules of good standard practice, must flow out to a good level coat free from runs, sags, pits, or other defects, and dry with reasonable promptness to a hard, somewhat elastic glossy coating which can be rubbed in 48 hours or less. The manufacturer is given wide latitude in the selection of raw materials and processes of manufacture, so that he may produce a varnish of the highest quality. The varnish must meet the following requirements:

Appearance.—Clear and transparent.

Color.—Not darker than a solution of 3 g. of potassium dichromate in 100 c.c. of pure sulphuric acid, specific gravity 1.84.

Flash Point (closed cup).—Not below 30° C. (85° F.).

Non-volatile Matter.—Not less than 45 per cent. by weight.

Set to Touch.—In not more than 4 hours.

Dry Hard.—In not more than 24 hours.

Toughness.—Film on metal must stand rapid bending over a rod 3 mm. (⅛ inch) in diameter.

Working Properties.—Must have good brushing, flowing, covering, leveling, and rubbing properties; and must show no impairment of lustre or other defect when used where natural or illuminating gases are burned or when subjected to air currents during the process of drying or application.

Water Resistance.—The dried film must stand application of cold water for not less than 18 hours without whitening or showing other visible defect.

NOTES FROM THE RESEARCH LABORATORY
EASTMAN KODAK COMPANY.*

A METHOD OF PRODUCING REVERSED DYE IMAGES.[1]
By J. I. Crabtree.

REVERSED dye images may be obtained on motion picture film or any other suitable support by first dyeing the film with a dye that is capable of being reduced to a leuco base, and after tinting, bleaching in an ordinary acid hypo-bath, washing, and then removing the silver image by using a solvent of silver such as Farmer's reducer. Two methods of procedure are described: The first method making use of a single bath containing the dye as well as the bleaching agent, and the second, dyeing or tinting the gelatin silver image in one bath and then bleaching it in a separate bath. In both cases the film is subsequently washed and then immersed in the reducing solution.

The success of the process is largely dependent on the careful adjustment of the time of bleaching. Thorough washing before the film is placed in the reducing bath is of importance, otherwise the leuco base is mordanted to the silver ferrocyanide image and on prolonged washing is oxidized to the dye. The result is the production of a positive dye image. This difficulty, along with several others, is mentioned, and suggestions are given for avoiding them. Several interesting effects may be obtained by slight variations of the procedure as: (1) Production of a toned silver image with the highlights tinted by substituting for the last reducing bath either a uranium-toning bath or a dye-toning bath; (2) line effects by increasing the time of bleaching and then toning as in (1); (3) unusual tinted effects by merely dyeing and bleaching and washing with slight increase of the bleaching time. The theory of the process is as follows: The dye (such as methylene blue) in the presence of hypo is locally reduced to the leuco base in the region of the silver image, and on washing, the leuco base is

---

washed out more rapidly than the dye, leaving a reversed dye image with silver in the highlights. Removal of the silver from the highlights then leaves the desired reversed dye image. (An interesting criticism of the article appears in the editorial column of the *B. J.*, 1921, p. 46.)

A Method for the Micro-analysis of Gases by the Use of the Pirani Pressure Gauge. RESEARCH STAFF OF THE GENERAL ELECTRIC COMPANY, London. (*Proc. Phys. Soc. London*, August 15, 1921.)—The method is applicable to gases at pressures of .1 to .001 mm. mercury, and is based upon a study of the pressures which are found as the temperature is raised. For each substance present there is a temperature at which a large change in the vapor pressure takes place. Below this " condensation temperature " there is practically no pressure due to the substance.

Let a mixture of vapors at low pressure be taken for analysis. Then a tube containing a single vapor should be prepared for each of the vapors that may be present. The mixture and the several tubes are raised in temperature after having been in a liquid air bath and the different pressures are measured. At some temperature there will appear a sudden increase in the pressure exerted by the mixture. Thereupon the pressures of the several tubes are examined. It may be that more than one will show a notable increase above its pressure at the low initial temperature. In that case the one with the highest condensation temperature is recognized as a constituent of the mixture. The raising of the temperature is then continued until again a rapid increase in pressure manifests itself, when a second constituent is identified, and so on.

For such a method there must be a means of measuring vapor-pressures with accuracy up to .1 mm. The Pirani gauge in a modified form was found to be suitable. A tungsten filament was joined in a bridge with three resistances having negligible temperature coefficients. The filament was placed in the space where the pressure was to be measured. As the pressure of the surrounding gas changed the resistance of the filament changed, owing to escape of heat at a different rate. The difference of potential applied to the bridge was adjusted so as to restore the original resistance of the filament. From the new applied P. D. the pressure can be read off from a calibration curve. It is claimed that this type of gauge has advantages in comparison with the McLeod instrument, though not in point of speed.

" This method is extraordinarily sensitive and certain. One per cent. of water in CO_2 may be detected—an unfavorable case because the main constituent evaporates before the impurity." After the constituents are known their amounts may be rapidly estimated.

G. F. S.

NOTES FROM NELA RESEARCH LABORATORIES.*

DECAY OF BIOLUMINESCENCE IN CYPRIDINA.

By William R. Amberson.

THE decay of luminescence in the Japanese ostracod, *Cypridina hilgendorfii*, Müller, has been studied by a photographic method. The light reaction in this animal is known to consist in the oxidation of a substrate, luciferin, catalyzed by an enzyme, luciferase. The former is obtained free from enzyme in aqueous solution by extraction of the dried and powdered animals with boiling water. Enzyme solutions are similarly obtained by cold water extraction.

Direct photometric study is not feasible, since (1) the decay is very rapid, and (2) it is often necessary to study two solutions simultaneously. Such simultaneous study of several solutions, to determine the effect of changes in concentration of enzyme or substrate, in oxygen tension, and so on, is made necessary by the fact that in aqueous solution luciferin oxidizes spontaneously even when no enzyme is present, and will not keep for successive measurements. All attempts at standardization of solutions have failed, but by dilution and simultaneous study of two portions of the same solution accurate relative values can be obtained.

Moving photographic records of the progress of the reaction are taken on negative motion picture film. Films are mounted and revolved on a kymograph. Solutions to be studied are placed in one-inch test tubes, blackened externally with the exception of a small vertical slit window 1.5 mm. wide, cut in a phosphor-bronze strip and applied to one side of the tube. This window is brought to a distance of one millimetre from the film. Two such tubes are arranged to give records running side by side upon one strip of film, and covering two-thirds of the film width. Measured luciferin solutions, of any desired concentrations, are placed in the tubes, and measured quantities of enzyme are added suddenly from pipettes at the proper moment. Films are moved past the windows at rates of from 4 to 10 mm. per second.

Calibration is achieved through the use of Cypridina light itself. Films upon which moving records have been impressed are

---

* Communicated by the Director.

clamped in a holder between two metal strips bent in the arc of a circle with a 15 centimetre radius. The inner strip carries a row of fifteen small round windows, in which photographic film filters of known transmissions are placed. This row of openings comes opposite to the unexposed third of the film. Filter transmission values range from 5 per cent. to 100 per cent. Illumination for calibration is secured from a test tube of Cypridina solution placed at the centre of the circle. During exposure this solution is stirred rapidly by motor, to insure complete mixing of enzyme and luciferin, as well as homogeneous radial distribution of the light. Fifteen calibration densities, corresponding to known relative intensity values are thus obtained upon development. Calibration exposures are for one minute. The films are then developed.

Photographic densities of both calibration and moving records are read by the optical pyrometer. Under the conditions of the experiment the two sets of values are comparable. A curve of blackening is drawn for each experiment, and the densities from the moving records are referred to it for the evaluation of intensities along the curves.

The following results are indicated:

(1) The decay curve for Cypridina luminescence assumes the form of a bimolecular reaction in which two reactants are present in equimolecular concentrations. The basic assumption in the work is that the light intensity, I, at any instant is a measure of the reaction velocity at that instant. Upon this assumption the experimental values are expressed by the usual equation, in which A is the initial concentration of reacting material and x the decrease in that concentration in the time t.

$$I = \frac{dx}{dt} = k(A-x)^2$$

This may be expressed in the straight line form,

$$\frac{1}{\sqrt{I}} = a + bt.$$

Where a

$$a = \frac{1}{A\sqrt{k}} \quad \text{and } b = \sqrt{k}$$

The experimental values are normally plotted in this form, since I and not $(A-x)$ is directly measured by the method. It has been a frequent practice among students of inorganic phosphorescence to plot their results in this form. The theory in such cases

has assumed the recombination of positive and negative ions, present in equal numbers in the phosphorescent material after separation by the action of previously incident radiation. There is therefore at least a superficial resemblance between the decay curves of inorganic phosphorescence and the curve for Cypridina. The nature of the two reactants in the Cypridina luminescence is not yet clear.

(2) With concentrated enzyme solutions the velocity of reaction is proportional to the concentration of the enzyme. This relationship has frequently been noted in other enzyme reactions.

Further studies are being made upon the relation of oxygen to the reaction, the temperature coefficient, the effect of luciferin concentration, and similar problems.

VISIBILITY CURVES FOR COLOR DEFECTIVES.

By Margaret C. Shields.

[ABSTRACT.]

THIS paper aims to determine just what deviations from the normal spectral luminosity curve are to be found in cases of partial color-blindness. The apparatus used is a Lummer-Brodhun spectro-photometer which has been in use at this laboratory for some time, and the method of determining the luminosity curve consists essentially in a photometric comparison of adjacent parts of the spectrum, so close together that the color difference in each photometric determination is, at the most, small enough to be negligible as a disturbing factor. Both the instrument and the method have been previously described.[1] The results were reduced to an energy basis.

The writer (a deuteranope) finds her own visibility maximum displaced from the normal (556–557$\mu\mu$) to 571$\mu\mu$. This is in accord with previous results in so far as they are specific on the point. Although previous work has shown different maxima in the visibility curve for different individuals,[2] the attempt has only occasionally been made to correlate these with the various types of color-defect. In one such case, a deuteranope reported

---

[1] *Astrophysical Journal,* vol. 35, p. 237; and vol. 48, p. 65.

[2] Watson, *Proc. Roy. Soc.,* vol. 88, p. 404; Tufts, *Phys. Rev.,* vol. 25. p. 433; Coblentz. *Bull. Bur. St.,* vol. 14. p. 167.

by Coblentz, the maximum of the visibility curve was shifted to 578$\mu\mu$. According to the results of Abney, interpreted on the basis of the three-process theory of color vision, the maximum should be at 590$\mu\mu$.

The three-process theory, just referred to, would seem to require that the total luminosity for a person lacking the green sense should be about 0.7 of normal; and for a red-blind person about 0.3. The writer's conclusion is that such a relation does not exist. For a light source at 2045° K., her own (deuteranope) curve and that of an unusually red-sensitive normal show just about the same deviation of maximum from that of the average normal, when all curves are plotted to equal area. No reason is apparent for reducing one of these curves more than the other. Plotting them to equal areas does not give an unduly high maximum in the red. The same is true of Coblentz's four cases with maxima in the red, but fails for the one with the maximum in the green.

A further attempt was made to answer the question as to the integral visibility, for the normal and for the color-blind, by making measurements of the absolute threshold throughout the spectrum. For the author, for the red-sensitive subject before mentioned, and for a normal, the thresholds lie, in the red end of the spectrum, in the order corresponding to the ordinates of the respective visibility curves, but this is not true in the green and blue.

The author's conclusions are (1) that an abnormal visibility function is not necessarily associated with color defect; (2) that color defect, on the other hand, *does* condition a definite modification of the visibility function. A theory of vision should interrelate brightness sense and color sense to account for this. (3) It still seems doubtful that color defect involves a lowered brightness sense such as would appear to be the inevitable consequence of the Young-Helmholtz theory.

NOTES FROM THE LABORATORY OF PURE SCIENCE, NELA RESEARCH LABORATORIES.*

ACCURACY IN COLOR-MATCHING.

By W. E. Forsythe.

THE color-temperature of an incandescent source has been defined as the temperature at which it is necessary to operate a black body so that the color of the integral light from the black body is the same as that from the source being studied. Since the light from all radiating substances cannot be accurately matched in color with that of a black body at a particular temperature, it is more accurate to define the color-temperature as that temperature of a black body at which the ratio of the radiant flux at some two arbitrarily chosen wave-lengths is the same as that for the radiating substance being investigated.

In general color-temperature measurements can be quite accurately made with an ordinary Lummer-Brodhun contrast photometer. The process of determining such temperatures is known as color-matching.

Two tests have been made of the accuracy of color-matching with an ordinary Lummer-Brodhun contrast photometer.

In the first test, several observers made color-matches using two tungsten lamps so set that there was an illumination of 5.1 foot-candles on the photometer screen. It was found that experienced observers agreed in their setting to an accuracy of about 3°K., while inexperienced observers differed by only about 5°K.

There was also a test made to see if there was any difference in the accuracy depending upon the illumination on the photometer screen. Tests were made by several observers for illumination varying from 1.8 to 45 foot-candles. There were no very definite differences in accuracy found for the different illuminations.

A lamp was very carefully color-matched with the color standard maintained by this Laboratory and sent to the Bureau of Standards to be compared with their standard of color. The aver-

---

age of the value obtained before it was sent to the Bureau of Standards and the value obtained after it was returned was 3087°K. The value found by the Bureau of Standards was 3085°K. Later a lamp was sent to this Laboratory from the Bureau of Standards and compared with the standard of this Laboratory. The values found by the two laboratories agree exactly, the value being 2848°K.

The above tests indicate the accuracy that may be obtained in such work both in making the color-matches and in determining the color-temperature scale in different laboratories.

NELA RESEARCH LABORATORIES,
    CLEVELAND, OHIO,
        November 16, 1921.

Two Forms of Isotopes.—In a communication to the *Chemical News* of October 28th, last, Prof. Bohuslay Brauner, of Prague, presents in some detail a study of the question of isotopy in connection with the international revision of atomic weights. Some chemists have expressed the view that the exact determination of these weights and the statement of them to several places of decimals have lost a good deal of importance. The atomic weights of an element may represent only that of the average mixture of its isotopes. Professor Brauner points out that at present two classes of isotopes are known. One class consists of radioactive elements, products of the same or different series of radioactive disintegration (Soddy's isotopes), the other class (isotopes of J. J. Thomson and Aston) represents mixtures of extremely similar elements, which were formerly regarded as individual elements respectively. To this class belong the chlorine isotopes obtained by Harkins.

The first class of isotopes descends from uranium or thorium and the different series end in " leads " of the atomic weights 206 and 208, but all such representing one place do not necessarily occur together. Those of the second class, so far as now known, always occur in association, in the same proportion, the mixture having always the same average combining weight. Aston has shown that separation can be affected by electromagnetic analysis, and that their atomic masses are represented by integers on the base $O = 16$. They run to-day from hydrogen to caesium. Incidental to these considerations, a modification of Mendeléef's law is necessary in regard to the isotopes, but it may still stand with reference to the pure elements. As a conclusion from his studies, Brauner recommends that the term " atomic masses " be used only for whole numbers of the isotopes of the second class, while the term " atomic weights " should be applied to the numbers obtained by chemical methods and the use of the balance, no distinction being made between pure elements, mixtures of isotopes or single isotopes.   H. L.

THE EFFECT OF SOME DECOLORIZING CARBONS UPON THE COLOR AND COLLOIDS OF CANE SUGAR.[1]

By Joseph F. Brewster and William G. Raines, Jr.

[ABSTRACT.] .

SUGAR cane juice in 3000-pound lots was clarified by sulphur-lime treatment and by kieselguhr-decolorizing-carbon filtration. In general, more colloidal matter is removed by treatment with kieselguhr alone than with sulphur dioxide and lime. The sulphur dioxide and lime treatment removes very little, if any, coloring matter, while the various carbons used showed different decolorizing power and different ability to remove colloids. The amount of total colloidal material present appears to affect the decolorization by carbons.

THE EFFECT OF VARYING HYDROGEN ION CONCENTRATION UPON THE DECOLORIZATION OF CANE JUICE WITH CARBON.[2]

By Joseph F. Brewster and William G. Raines, Jr.

[ABSTRACT.]

COMPARATIVE decolorization of sugar cane juice at varying hydrogen ion concentrations was determined by adjusting the re-action of the juice by the addition of acid or alkali, treating with decolorizing carbon, boiling, and filtering. The color remaining in the samples was then read with the aid of the Hess-Ives tint photometer and the color units obtained. Determinations were made at p_H values ranging from 8 to 4. In general, best decolorization is obtained at $p_H = 4$. At this acidity, however, inversion is rapid, and it is doubtful whether much advantage is to be gained in practice by working at such acidity. It would be necessary to maintain careful control.

THE ODOROUS CONSTITUENTS OF PEACHES.[3]

By Frederick B. Power and Victor K. Chesnut.

[ABSTRACT.]

No information on the nature of the substances to which the odor of the peach is due appears to have been recorded in chemical literature. Although many preparations designated as " peach oil " or " peach essence " have long been in use for flavoring purposes, they consist for the most part of purely empirical mixtures of esters and essential oils with other more specific aromatic substances.

In the present investigation only the fresh pulp of ripe Georgia Belle peaches was employed, and the pits were carefully excluded.

The results of the investigation and the conclusions therefrom may be summarized as follows:

1. The odorous constituents of the peach may be said to consist chiefly of the linalyl esters of formic, acetic, valeric, and caprylic acids, together with a considerable proportion of acetaldehyde and a very small amount of an aldehyde of higher molecular weight. It is probable that the volatile acids are present to some extent in a free state.

2. A minute amount of acetaldehyde is contained in the emanation from the entire ripe fruit.

3. No trace of hydrocyanic acid or benzaldehyde could be detected in the distillate from peach pulp. It may therefore be concluded that the occurrence of the glucoside amygdalin is restricted to the kernels of the fruit, and that no other compound capable of yielding hydrocyanic acid is present in the pulp.

4. By extracting a concentrated distillate of the peach with ether, a very small quantity of an essential oil was obtained. This was a pale yellow, limpid liquid, which possessed an exceedingly fragrant and intense peach-like odor. When cooled somewhat below the ordinary temperature, it formed a concrete, transparent mass, interspersed with minute, acicular crystals. These crystals evidently consisted of a paraffin hydrocarbon, which, when indirectly isolated, melted at about 52°. The yield of essential oil was 0.00074 per cent. of the weight of pulp employed.

In addition to the esters mentioned, the peach oil contained a little acetaldehyde and furfural, the latter having doubtless been

---

[3] Published in *J. Am. Chem. Soc.* (1921), **43**: 1725.

produced during the process of distillation by the action of organic acids on the sugar contained in the fruit. The presence of cadinene, or a compound giving a similar color reaction, was also indicated.

The essential oil of peach is a very unstable product. When kept for a comparatively short time in a glass tube with a capillary constriction and only occasionally exposed to the air, it became converted into a black, viscid mass, and had then completely lost its original fragrance. This change is in accordance with the character of the constituents of the oil as determined by the present investigation. If the oil, as first obtained, be brought into a glass tube, and hermetically sealed, it appears to be capable of preservation for an indefinite period.

Astronomy at the Antipodes. The *New Zealand Journal of Science and Technology* gives an account of offers recently made by Yale University of apparatus for use in a New Zealand Observatory, in order to make systematic studies of the southern sky. New Zealand is about as far south of the equator as New Haven is north, the fortieth parallel of south latitude passing through it. The offer was made through Dr. Frank Schlesinger, Director of the Yale Observatory, who since 1915 has been constantly interested in the matter. Funds having been made available, it is now possible to make the following offers to the New Zealanders. To provide a telescope with six-inch aperture, mounting driving clock and plate-glass photographic plates. This is to be used in photographing the southern sky, and when such work has been accomplished, outfit is to be returned to Yale, unless provision is made for further use in New Zealand.

To provide a large photographing telescope, the optical parts of which will cost about $25,000. The complete instrument will be worth about $100,000. With this Yale will send two astronomers to undertake urgently required observations on southern stars. These observers will use the outfit about half the time, the other half being available for local workers. The outfit will be left in place, if a satisfactory site can be secured, and New Zealand prepared to assist in providing land, buildings, foundations, offices and residences for the staff.

These offers are considered very liberal, and it is claimed by members of the New Zealand Astronomical Society that their territory offers the best opportunities for the examination of the southern sky by modern methods.

H. L.

Thermal Conductivity and Diffusivity of Concrete. (A. P. CARMAN and R. A. NELSON, Bulletin 122, Engineering Experiment Station, University of Illinois.)—As a result of the rapidly increasing use of concrete in various forms of construction it has become important to have some definite information as to the thermal conductivity and diffusivity of different concrete mixtures.

During the last ten years the composition and methods of preparation of concrete mixtures have been studied and standardized, and present investigators have had the advantage of dealing with concrete mixtures which can be described much more definitely than was possible a few years ago. The results of only a few determinations of the thermal conductivity of concrete have been published previously, and to a large extent these lack definiteness in regard to the composition and method of preparation of the material.

Attempts to Detact the Presence of Neutrons in a Discharge Tube. J. L. GLASSON. (*Phil. Mag.,* Oct., 1921.)—Last year Sir Ernest Rutherford suggested the existence of a substance having zero electric charge on its nucleus. Such a nucleus might come into existence if an ordinary hydrogen atom were to meet some experience that would make its solitary electron fall into the positive nucleus. Since the positive charge of the nucleus equals the negative charge of the electron the resultant neutron would have no residual charge.

Search was made for the hypothetical neutron in the place where there was a chance of finding it, that is among the positive rays of a hydrogen discharge tube where free hydrogen nuclei and electrons abound. No evidence of its existence was discovered. Should subsequent investigation detect this elusive particle, it will facilitate the labors of those who seek to learn the structure of nuclei.

G. F. S.

On the Spectra of Lead Isotopes. T. R. MERTON. (*Proc. Royal Soc.,* A 702.)—About a year ago this investigator showed that the strongest line in the arc spectrum of lead of length 4058 angstrom units has slightly different wave-lengths when lead specimens of different ancestry are used. The measured wave-length got with lead from pitchblende exceeded that given by ordinary lead by .005 of a unit, while the length from ordinary lead in turn was greater than that obtained by the use of the metal derived from thorite by .002 unit. Owing to the possession of a considerable quantity of lead derived from Australian Carnotite it has become possible to extend the investigation to four lines altogether. In every case it has been found that the wave-length of the Carnotite lead is greater than that of ordinary lead. For the line cited above the difference amounts to .011 unit. Thus the isotopes are winning a secure place in good physical society.

G. F. S.

NOTES FROM THE U. S. BUREAU OF MINES.[*]

PRESENT STATUS OF COAL CARBONIZATION AT LOW TEMPERATURES.

By Joseph D. Davis.

FOR the past twenty years an enormous amount of experimental work has been done in this country and in Europe on the carbonization of coal at low temperatures. Most of this work has been carried out on a laboratory scale, or at least on a semi-commercial scale, and only recently have results been obtained that can be used directly by the carbonization engineer. One object in view in the experimental work has been to learn from a purely scientific standpoint more of the composition of coal and its thermal decomposition. Another object has been the discovery and commercial development of more economical methods for processing fuels than the well-known high-temperature methods.

The problem of coal constitution and thermal decomposition is a long way from solution, although considerable progress has been made. Of the chemical constitution of coal, little is known as yet, but the yield of distillation products obtained under fixed temperature conditions, as well as their general nature, has been empirically worked out; the actual chemical reactions involved, however, have not been fully explained.

The technical application of low-temperature carbonization is still in its infancy and development has been slow, mainly for three reasons: (1) adequate fundamental knowledge of coal constitution and thermal decomposition is lacking; (2) evolution of suitable retorting apparatus is slow, owing to the low-heat conductivity of coal and the consequent difficulty of designing retorts which have appreciable capacity and also the requisite low-temperature gradients; (3) a market for the rather special distillation products, however valuable they may prove to be in the future, does not exist and must be created. Also, in order that a low-temperature industry may be firmly established, it is necessary that the popular prejudice against soft coke be overcome, and it will take time to accomplish this.

---

[*] Communicated by the Director.

It does not appear that low-temperature methods are destined soon to occupy an important place in the gas industry in so far as gas for city supply is concerned. They may, however, be used to advantage in the production of industrial gas. Details as to low-temperature methods and the amount and character of products obtained are presented in a recent paper published by the Bureau, which was presented before the meeting of the American Gas Association at Chicago on November 9, 1921.

ROCK DRILLING TESTS IN THE TRI-STATE MINING DISTRICT.

By C. R. Forbes.

During the past few years the questions of rock drills, drill bits and drill steel have received much attention, and many improvements have been brought about, both in the design and in the use of rock drills and drilling equipment. Among these improvements the use of smaller changes in gage between the different steels has been one of the most important. With the old types of piston drill, gage changes of ¼ inch or more were often used, necessitating the use of steel of from 3 to 3½ inches in diameter to start when deep holes were to be drilled. As the work of drilling varies almost directly with the quantity of material removed, the use of these large sizes of steel resulted in a great loss of time and energy. At the present time, many companies are successfully using gage changes of $^1/_{16}$ inch, and in some cases changes of only $^1/_{32}$ inch are used. Although these very small changes require great care and accuracy on the part of the drill sharpener, both in forging and gaging the steels and in proper heat treatment, still the cost of this extra work in the drill shop is more than offset by the increased efficiency of the drilling machines. Another improvement in drilling practice that has been brought about recently by several companies is the use of 1-inch steel in place of 1¼ inch in the large mounted hammer drills. The advantage of the smaller cross-section consists in the saving in steel, faster drilling speed, and saving in labor on the part of the miner in handling the lighter steel.

In order to find out whether or not these improvements were applicable in the Missouri-Kansas-Oklahoma districts, the Mississippi Valley experiment station of the Bureau of Mines, work-

ing in coöperation with the Missouri School of Mines and Metallurgy, conducted a series of experiments extending over a period of four months, beginning May 1, 1921. The tests were made by I. F. and J. H. Hodges, senior students from the Missouri School of Mines and Metallurgy, who had had considerable practical experience as miners. The work was done in the Bluebird mine of the O. M. Bilharz Mining Company, near Commerce, Oklahoma, and was under the immediate supervision of F. H. Gartung, superintendent for that company.

The conclusions from the tests are as follows: (1) One-eighth-inch gage change and 24-inch changes in steel lengths are best for conditions in this district when using 1¼-inch steel; (2) one-inch steel can be used successfully, with the large hammer drills for drilling holes up to ten feet in depth, at a considerable saving in time and energy on the part of the miner. Gage changes of $^1/_{16}$ inch and changes in steel lengths of 24 inches can be used with the one-inch steel. The tests are described more fully in a recent paper issued by the Bureau. Further work along this line is being conducted by the mines.

BENTONITE.

By Raymond B. Ladoo.

The name bentonite has been applied to a group or series of clay-like materials characterized by an alkaline oxide and alkaline earth content of 5 to 10 per cent., fine grain size, high-absorptive powers, and usually very strong colloidal properties. It varies considerably in composition and physical properties. It is often light yellow, but may be cream to black. It is exceedingly fine grained, very plastic and highly absorbent; when wetted it will absorb more than three times its weight or seven times its volume of water. Some varieties when wetted with water expand to more than six times (some experimenters report eight times) their original volume. The wetted material is exceedingly smooth and soft and feels like soft soap. Unlike most clays, bentonite is easily fusible at a comparatively low temperature.

Some varieties when finely ground and thoroughly agitated with water will stay in suspension indefinitely, forming a translucent gelatinous mass. The addition of small amounts of acids or sodium chloride seems to have little or no tendency to aid coagula-

tion or settling. Other varieties go into suspension more easily, but settle out again.

Some, and perhaps all, of the minerals of the bentonite group have the property of allowing easy replacement of the alkaline and earth oxides, one with another. This property has been utilized for the softening of certain types of hard water.

It has been mined in Wyoming, California, South Dakota, and occurs also in Montana, Arizona, Utah, Texas, Tennessee, Idaho, New Mexico, and British Columbia.

It has been used principally in the manufacture of anti-phlogistine, dressing for horses' hoofs, retarder in plaster, filler in paper and soap, as an adulterant in drugs and candy. In recent years its unusual properties have attracted considerable attention, and research work has been undertaken to study this material and to develop the best methods for its utilization, especially by the Forest Products Laboratory of the Department of Agriculture, Madison, Wisconsin, in paper making and de-inking news print. Other uses suggested are as a filler for rubber, phonograph records, textiles, cordage, electrical insulation and leather; in the manufacture of paint and adhesive paste; for de-watering crude petroleum; as a base for massage creams, printer's inks, and precipitating lake colors. Further details are given in a paper recently issued by the Bureau.

Studies on Cooling of Fresh Concrete in Freezing Weather. (TOKUJIRO YOSHIDA, Bulletin 123, Engineering Experiment Station, University of Illinois.)—The practice of placing concrete in freezing weather renders important a knowledge of the rate at which this material will cool, and the effect of the various methods of protecting the freshly placed concrete from the cold.

This bulletin deals with certain experimental work carried on at the Experiment Station with the object of obtaining data on the length of time required for concrete of a given temperature to lose its heat and become cold enough to freeze when it is exposed to temperature lower than the freezing point of water. Some experiments were made on the protective effect of coverings.

While it is probable that these experiments do not give complete data regarding concreting in freezing weather under all possible conditions, it is considered that they throw some light on the behavior of fresh concrete at low temperatures, and indicate the necessity of protection or other precautions.

THE FRANKLIN INSTITUTE.

Additions to membership, since last report, 9.

Reports of progress were presented by the Committee on Library and the Committee on Science and the Arts.

The following nominations were made for officers and managers to be voted for at the annual election to be held on January 18, 1922:

For President (to serve one year) Walton Clark.

For Vice-President (to serve three years) Henry Howson.

For Treasurer (to serve one year) Benjamin Franklin.

For Managers (to serve three years) Francis T. Chambers, W. C. L. Eglin, Alfred C. Harrison, Nathan Hayward, Charles A. Hexamer, Robert W. Lesley, Marshall S. Morgan, E. H. Sanborn.

For Managers (to serve two years) Clarence A. Hall, Haseltine Smith.

The paper of the evening on "The Application of the Fundamental Knowledge of Portland Cement to Its Manufacture and Use" was presented by P. H. Bates, A.B., B.S., Chief, Structural and Miscellaneous Materials Division, Bureau of Standards, Washington, D. C.

The results of various attempts to determine the mineral constituents of Portland cement, culminating in the successful attempt of Rankin, were reviewed. The work of the Bureau of Standards in determining the physical properties of the different constituents was described. The relative amounts of these occurring in cement of normal manufacture, and the possibility and economy of producing, in the process of manufacture, the determined amount of any constituent were discussed. The quality of cements of relatively the the same composition but different constitution, the desirability of more refined methods of testing to determine the qualities not revealed by present tests and the need of cements of different qualities for different uses were also considered. The subject was illustrated by lantern slides. After a brief discussion, a unanimous vote of thanks was extended to the speaker.

Adjourned.

R. B. OWENS,

Secretary.

125

COMMITTEE ON SCIENCE AND THE ARTS.

(Abstract of Proceedings of Stated Meeting held Wednesday,
December 7, 1921.)

HALL OF THE INSTITUTE,
PHILADELPHIA, December 7, 1921.

DR. H. J. M. CREIGHTON *in the Chair.*

The following report was presented for final action:

No. 2761 : Greaves-Etchells Electric Arc Furnace. The Certificate of Merit to Messrs. H. A. Greaves and Harry Etchells, of Sheffield, England.

The following report was presented for first reading:

No. 2781
and   } The Franklin Medal.
No. 2782

R. B. OWENS,
Secretary.

SECTIONS.

Section of Physics and Chemistry.—A meeting of the Section was held in the Hall of the Institute on Thursday evening, November 10th, at eight o'clock, with Dr. Thomas D. Cope in the Chair. The minutes of the previous meeting were approved as read.

Albert W. Hull, Ph.D., of the Research Laboratory of the General Electric Company, Schenectady, New York, delivered an address on " The Crystal Structures of the Common Elements." A description was given of the apparatus for the analysis of crystals by means of the X-rays. The available data on this subject were reviewed and summarized. The lecture was illustrated with lantern slides. The paper was discussed; a vote of thanks was extended to Doctor Hull; and the meeting adjourned.

JOSEPH S. HEPBURN,
Secretary.

Section of Physics and Chemistry.—A meeting of the Section was held in the Hall of the Institute on Thursday evening, December 1, 1921, at 8 o'clock. Dr. Harry F. Keller in the Chair. The minutes of the previous meeting were read and approved.

Eugene T. Allen, Ph.D., Reseach Chemist, Geophysical Laboratory of the Carnegie Institution, Washington, D. C., presented a communication entitled, " Chemical Aspects of Volcanism," in which the origin of volcanic gases and the factors influencing their chemical composition were discussed. The address was illustrated with lantern slides.

The paper was discussed by Mr. Fulweiler, Doctors Ehrenfeld and Allen, and others. On motion of Dr. George A. Hoadley, a vote of thanks was tendered Doctor Allen.

The meeting then adjourned.

JOSEPH S. HEPBURN,
Secretary.

MEMBERSHIP NOTES.

ELECTIONS TO MEMBERSHIP.

(Stated Meeting, Board of Managers, December 14, 1921.)

RESIDENT.

MR. FRANCIS J. CHESTERMAN, The Bell Telephone Company of Pennsylvania, Philadelphia, Pennsylvania.

DR. FREDERICK EHRENFELD, University of Pennsylvania, Philadelphia, Pennsylvania.

MR. J. M. HAMMOND, 1429 N. 21st Street, Philadelphia, Pennsylvania.

MR. JOSEPH A. MARTCCELLO, 229 N. Thirteenth Street, Philadelphia, Pennsylvania.

DR. FREDERIC PALMER, JR., Department of Physics, Haverford College, Haverford, Pennsylvania.

MR. HASELTINE SMITH, 326 Walnut Street, Philadelphia, Pennsylvania.

MR. C. A. WOODBURY, E. I. du Pont de Nemours and Company, Chester, Pennsylvania.

NON-RESIDENT.

DR. ARTHUR P. TANBERG, E. I. du Pont de Nemours and Company, Henry Clay, Delaware.

ASSOCIATE.

MR. ALFRED ERNE, 5217 DeLancey Street, Philadelphia, Pennsylvania.

CHANGES OF ADDRESS.

DR. A. M. COMEY, 380 Mt. Auburn Street, Cambridge, Massachusetts.

MR. KERN DODGE, 5135 Pulaski Avenue, Germantown, Philadelphia, Pennsylvania.

MR. W. E. FLETCHER, 4609 Osage Avenue, Philadelphia, Pennsylvania.

MAJOR THOMAS H. GRIEST, The Bell Telephone Company, 261 N. Broad Street, Philadelphia, Pennsylvania.

DR. EDWARD MARBAKER, Mellon Institute, Pittsburgh, Pennsylvania.

MR. WM. H. RICHMOND, Box 226, Daytona Beach, Florida.

MR. JOHN B. RUMBOUGH, P. O. Box 2, Ashville, North Carolina.

NECROLOGY.

Prof. B. H. Hite, Morgantown, West Virginia.

LIBRARY NOTES.

PURCHASES.

ADAMS, ROGER, and others. [ed.]—Organic Syntheses. 1921.

AITCHISON, LESLIE.—Engineering Steels. 1921.

American Institute of Mining and Metallurgical Engineers.—Pyrometry. 1920.

California State Railroad Commission.—Inductive Interference. 1919.

GRIFFIN, ROGER CASTLE.—Technical Methods of Analysis. 1921.

HERING, RUDOLPH, and GREELY, SAMUEL A.—Collection and Disposal of Municipal Refuse. .1921.

HOYT, SAMUEL L.—Metallography, 2 vols. 1920-21.

HUYGENS, CHRISTIAAN.—Oeuvres Complètes, vols. 13 and 14. 1916-20.

KNECHT, EDMUND, and HIBBERT, EVA.—New Reduction Methods in Volumetric Analysis. 1918.

HOWSON, E. T., and others. [ed.]—Maintenance of Way Cyclopedia. 1921.

PORTER, J. EDWARD.—Bibliography of the Activated Sludge Process of Sewage Treatment. 1921.

GIFTS.

Ajax Electrothermic Corporation, Ajax-Northrup High-frequency Induction Furnace. Trenton, New Jersey, no date. (From the Corporation.)

Allen Cone Company, Bulletin No. 20 on Allen Sand Tanks. El Paso, Texas, no date. (From the Company.)

Allen, John F., Company, Riveting Machines. New York City, New York, no date. (From the Company.)

Allis-Chalmers Manufacturing Company, Bulletin No. 1115 on Alternating Current Generators and Bulletin No. 1819 on Electric Hoists. Milwaukee, Wisconsin, 1921. (From the Company.)

American Gas Furnace Company, Bulletin No. 12 on Carbonizing Machines. Elizabeth, New Jersey, no date. (From the Company.)

American Society of Civil Engineers, Index to Transactions, 1867 to 1920, Transactions, vol. lxxxiv. New York City, New York, 1921. (From the Secretary.)

American Society of Heating and Ventilating Engineers, 1921 Year-book. New York City, New York, 1921. (From the Society.)

Armour Institute of Technology, General Information. Chicago, Illinois, May, 1921. (From the Institute.)

Arnessen Electric Company, Inc., Bulletin No. 471 K, Marine Electrical Equipment. New York City, New York, no date. (From the Company.)

Ashworth and Parker, Booklet on the Parker Engine. Bury, England, no date. (From the Company.)

Baker, Joseph, Sons, and Perkins, Ltd., Booklet on Baker's Patent Speed Gears. London, England, 1921. (From the Company.)

Barber-Green Company, Belt Conveyors, Self-feeding Bucket Loaders. Aurora, Illinois, 1920. (From the Company.)

Beaumont, R. H., Company, Catalogue 36, The Right Way with Ashes, and Catalogue 40, Coal and Ash Handling Systems for Boiler Houses. Philadelphia, Pennsylvania, 1921. (From the Company.)

Benjamin Electric Manufacturing Company, Catalogue No. 23 on Electrical Products. Chicago, Illinois, no date. (From the Company.)

Best, C. L., Gas Traction Company, Best Tracklayer Sixty Tractor. San Leandro, California, no date. (From the Company.)

Bigelow Company, Booklets on Water Tube Boilers and Return Tubular Boilers. New Haven, Connecticut, no date. (From the Company.)

Blanchard Machine Company, Data Book on Blanchard High-power Vertical Surface Grinder. Cambridge, Massachusetts, no date. (From the Company.)

Bridge, David, and Company, Ltd., Booklet on Gearing and Hauling Installations. London, England, no date. (From the Company.)

Brubaker, W. L., and Brothers, Catalogue No. 6 of Taps and Dies. New York City, New York, no date. (From the Company.)

Burton-Rogers Company, The Cadmium Test. Boston, Massachusetts, no date. (From the Company.)

Buxton, George E., Address on Wage Incentives and Production. Springfield, Massachusetts, October, 1921. (From the Author.)

Byers, A. M., Company, Bulletins 26, 27, 30, 32, 34, 38 and 41. Pittsburgh, Pennsylvania, 1921. (From the Company.)

Carnegie Endowment for International Peace, Year-book, 1921. Washington, District of Columbia, 1921. (From the Secretary.)·

Chisholm-Moore Manufacturing Company, Catalogue 25 on Hoists, Trolleys and Cranes. Cleveland, Ohio, no date. (From the Company.)

Codd, E. J., Company, Booklet on Chain Furnace Screens. Baltimore, Maryland, no date. (From the Company.)

Consolidated Expanded Metal Companies, Booklet on Steelcrete Slab Tables, and a Handbook of Design. Braddock, Pennsylvania, no date. (From the Companies.)

Conveyors Corporation of America, Booklet, The Proof of the Pudding. Chicago, Illinois, no date. (From the Corporation.)

Council of Arts and Manufactures of the Province of Quebec, 1921-22 Catalogue of Day and Evening Classes. Montreal, Canada, 1921. (From the Council.)

Cuerpo de Ingenieros de Minas y Aguas, Anales del Congreso Nacional de la Industria Minera, Tome II, V, and VI. Lima, Peru, no date. (From the Corps of Engineers.)

Cullman Wheel Company, Catalogue No. 12 on Sprockets. Chicago, Illinois, no date. (From the Company.)

Dawnay, Archibald D., and Sons, Ltd., Handbook of Design of Constructional Steel Work. London, England, no date. (From the Company.)

Despatch Manufacturing Company, Catalogue III on Despatch Electric Ovens. Minneapolis, Minnesota, no date. (From the Company.)

Detrick, M. H., Company, Catalogue on Detrick Hagan Steam Jet Ash Conveyor. Chicago, Illinois, no date. (From the Company.)

Dorr Company, The Treatment of Sewage and Industrial Waste Waters. Bulletin No. 20. New York City, New York, 1921. (From the Company.)

Dravo Contracting Company, Bulletins 110 to 116 inclusive on Inland Waterway Harbor Floating and Terminal Equipment. New York City, New York, no date. (From the Company.)

Dunlop and Ranken, Ltd., Steel Stock Catalogue. Leeds, England, no date. (From the Company.)

Electric Storage Battery Company, Bulletin on Charging Equipment for Exide

Batteries. Philadelphia, Pennsylvania, October, 1921. (From the Company.)

Fairbanks Company, Automobile and Service Station Equipment. New York City, New York, no date. (From the Company.)

Flory, S., Manufacturing Company, Catalogue No. 33 on Capstans. Bangor, Pennsylvania, no date. (From the Company.)

Gear Grinding Company, Ltd., Booklet on Motor Car Gear Box Production. Handsworth, Birmingham, England, January, 1921. (From the Company.)

Georgetown University, General Catalogues for 1916-1917, 1919-1920 and 1920-1921. Washington, District of Columbia. (From the University.)

Gillis and Geoghegan, Folder of Pamphlets on Telescopic Hoists. New York City, New York, 1921. (From the Company.)

Goucher College, College Bulletins for April and July, 1915; April, July and August, 1916; February, 1917; August, 1918; August and December, 1919, and June and April, 1920; Directories of Alumnæ and Non-graduates, January, 1915, and February, 1918; Bulletin on War Activities, February, 1919, and Catalogues, February and August, 1920. Baltimore, Maryland. (From the College.)

Greaves-Klusman Tool Company, Pamphlets on Lathes. Cincinnati, Ohio, no date. (From the Company.)

Hadfield-Penfield Steel Company, Booklets: Fuel Oil Engines, Horizontal and Vertical Types. Bucyrus, Ohio, no date. (From the Company.)

Hardinge Company, Catalogue No. 9 of Pulverized Fuels. New York City, New York, September, 1921. (From the Company.)

Harvard University, Contributions from the Jefferson Physical Laboratory, for 1919 and 1920. Cambridge, Massachusetts, 1921. (From the University.)

Hi-Voltage Equipment Company, Bulletin No. 2 on Lightning Arresters, Choke Coils and Fuses. Cleveland, Ohio, 1921. (From the Company.)

Ingersoll-Rand Company, Handbook for Four Tool Compressor Cars and Bulletin on Air and Gas Compressors. New York City, New York, August, 1921. (From the Company.)

Institution of Automobile Engineers, Session 1920-1921, Proceedings, and Index, vols. xi-xv. London, England. (From the Institution.)

International Railway Fuel Association, Proceedings of the Twelfth Annual Convention. Chicago, Illinois, May, 1920. (From the Association.)

Irving Iron Works Company, Catalogue 3A. Long Island City, New York, 1921. (From the Company.)

Kansas State Board of Agriculture, Report No. 155 on Wheat in Kansas. Topeka, Kansas, 1921. (From the Board.)

Kearney and Trecker Company, Catalogue No. 22 of Milwaukee Milling Machines. Milwaukee, Wisconsin, no date. (From the Company.)

Kinite Company, Booklet on Kinite. Milwaukee, Wisconsin, no date. (From the Company.)

Layne and Bowler Company, Booklet on Water Supply and Turbine Pumps. Memphis, Tennessee, no date. (From the Company.)

LeBlond, R. K., Machine Tool Company, Booklets on Multi-cuttings and Multi-cut Lathes. Cincinnati, Ohio, 1920. (From the Company.)

Leeds and Northrup Company, Bulletin 767. Philadelphia, Pennsylvania, 1921. (From the Company.)

Lincoln Memorial University, Catalogue 1921-1922. Harrogate, Tennessee. (From the University.)

Link-belt Company, Book No. 215 on Belt Conveyors. Philadelphia, Pennsylvania, 1921. (From the Company.)

Louisiana State University, Catalogue 1921. Baton Rouge, Louisiana, May, 1921. (From the University.)

McGill University, Calendar 1920-1921. Montreal, Canada, 1920. (From the University.)

Marryat and Scott, Booklet on Lifts. London, England, 1921. (From the Company.)

Massachusetts Department of Public Utilities, Annual Report for 1920, vols. i and ii. Boston, Massachusetts, 1921. (From the Department.)

Metals Coating Company of America, The Schoop Metal Spraying Process. Philadelphia, Pennsylvania, no date. (From the Company.)

Michigan Stamping Company, Bulletin No. 10. Detroit, Michigan, 1921. (From the Company.)

Mont Blanc l'Observatoire Meteorologique Physique et Glaciaire, Annales tome vii. Paris, France, 1917. (From the Observatory.)

Morris, Herbert, Ltd., Pamphlets Nos. 77, 78, 90 and 97. Loughborough, England, no date. (From the Company.)

National Physical Laboratory, Report for 1920. London, England, 1921. (From the Laboratory.)

New York City Department of Health, Keep-well Leaflet No. 21. New York City, New York, no date. (From Dr. Walton Clark.)

New York Public Service Commission, Report for 1917 on Statistics of Light, Heat and Power Companies. New York City, New York, 1918. (From the Commissioners.)

Niles-Bement-Pond Company, Progress Reporter, No. 29. New York City, New York, no date. (From the Company.)

Northern Engineering Works, Catalogues Nos. 28, 43 and 45 on Cranes and Hoists. Detroit, Michigan, no date. (From the Works.)

Oberlin College, Annual Catalogue, January, 1921. Oberlin, Ohio. (From the College.)

Oliver-Barth Jack Company, Catalogue No. 1 on Jacks. Milwaukee, Wisconsin, 1921. (From the Company.)

Oxweld Acetylene Company, Oxweld Can Do It. Newark, New Jersey, no date. (From the Company.)

Parsons, C. A., and Company, Ltd., Pamphlet on End Tightened Reaction Blading. Newcastle-on-Tyne, England, 1921. (From the Company.)

Pawling and Harnischfeger Company, Bulletin No. 56X on Excavating Equipment. Milwaukee, Wisconsin, no date. (From the Company.)

Pease, C. F., Company, Catalogue B Revised. Chicago, Illinois, no date. (From the Company.)

Petters, Limited, Booklets on Oil Engines. Yeovil, England, July, 1921. (From the Company.)

Philadelphia Department of City Transit, Annual Report for 1920. Philadelphia, Pennsylvania. (From the Department.)

Pittsburgh, Cincinnati, Chicago and St. Louis Railroad Company, Fourth Annual Report. Pittsburgh, Pennsylvania, 1920. (From the Secretary.)

Polytechnic Institute of Brooklyn, Catalogues of the College of Engineering, 1919-1922. Brooklyn, New York. (From the Institute.)

Power Specialty Company, Bulletin 300 on The Foster Superheater. Chicago, Illinois, September, 1921. (From the Company.)

Purdue University, Annual Catalogue, 1920-1921. Lafayette, Indiana, 1921. (From the University.)

Queensland Under Secretary for Mines, Annual Report for 1920. Queensland, Australia, 1921. (From the Secretary.)

Reliance Electric and Engineering Company, Bulletin 1014 on Reliance Adjustable Speed Motors. Cleveland, Ohio, August, 1917. (From the Company.)

Rutgers College, Annual Catalogue 1920-1921. New Brunswick, New Jersey, 1921. (From the College.)

Ryerson, Joseph T., and Son, Bulletin 1301 on Selective Geared Head Engine Lathes. Chicago, Illinois, no date. (From the Company.)

Sanitation Corporation, Bulletin G-6 on Hydraulic and Sanitary Equipment. New York City, New York, no date. (From the Corporation.)

" S-C " Regulator Manufacturing Company, Booklet on Feed Water Regulation. Fostoria, Ohio, no date. (From the Company.)

Smith and Serrell, Bulletins Nos. 32 and 33 on Flexible Couplings. Pittsburgh, Pennsylvania, 1921. (From the Company.)

Smithsonian Institution, Annual Report of the Board of Regents. Washington, District of Columbia, 1919. (From the Institution.)

Stanford University, University Publication, Biological Sciences, vol. ii, No. 2. Stanford University, California, 1921. (From the University.)

Stanton Ironworks Company, Ltd., Booklet on The Stanton Hume Reinforced Concrete Pipe. Nottingham, England, no date. (From the Company.)

Steel City Electric Company, Catalogue No. 33. Pittsburgh, Pennsylvania, May, 1918. (From the Company.)

Sturtevant, B. F., Company, Catalogue No. 282, High Humidity Dry Kilns. Hyde Park, Boston, Massachusetts, September, 1921. (From the Company.)

Swarthmore College, Catalogue. Swarthmore, Pennsylvania, 1920. (From the College.)

Swedish Chamber of Commerce of the United States, Sweden as Producer of Wood Goods, Pulp, Paper, Tar and other Forest-Products. New York City, New York. (From the Swedish Chamber of Commerce.)

Taylor Machine Company, Booklet on Taylor Principle Oil Engines. Chicago, Illinois, no date. (From the Company.)

United Engineering and Foundry Company, Bulletins FR and F. Pittsburgh, Pennsylvania, no date. (From the Company.)

United States Geological Survey, Professional Paper No. 123 on A Superpower System for the Region between Boston and Washington. Washington, District of Columbia, 1921. (From the Survey.)

United States Rubber Company, Catalogue of Packings. New York City, New York, no date. (From the Company.)

University of Akron, Annual Catalogue, 1917, 1918, 1920 and 1921. Akron, Ohio. (From the University.)

University of Chicago, Circular of Information, April, 1921. Chicago, Illinois. (From the University.)

University of Cincinnati, Announcement of Courses, 1921-1922. Cincinnati, Ohio. (From the University.)

University of Oklahoma, General Catalogue 1920-1921. Norman, Oklahoma, March, 1921. (From the University.)

University of South Carolina, Catalogue 1920-1921. Columbia, South Carolina, April, 1921. (From the University.)

University of Toronto, Calendar 1920-1921. Toronto, Canada. (From the University.)

Watts Brothers, Ltd., List No. 5 of Portable Boring Machine and Booklet on Modern Woodworking Machines. Sheffield, England, no date. (From the Company.)

Western Reserve University, Reports of the President and Other Officers, 1920-1921. Cleveland, Ohio, September, 1921. (From the University.)

Westinghouse Electric and Manufacturing Company, Reprint No. 91. East Pittsburgh, Pennsylvania, no date. (From the Company.)

West Virginia University, Catalogue and Announcements 1920-1921. Morgantown, West Virginia, July, 1921. (From the University.)

Wheeler Condenser and Engineering Company, Catalogue No. 108C of Centrifugal Pumps. Carteret, New Jersey, 1921. (From the Company.)

Wilson, John H., and Company, Ltd., Catalogue 55W of Deck Machinery. London, England, 1921. (From the Company.)

Wisconsin Geological and Natural History Survey, Bulletin No. 55, Soil Survey of Northern Wisconsin and Bulletin No. 58, Geography and Economic Development of Southeastern Wisconsin. Madison, Wisconsin, 1921. (From the State Geologist.)

Wyer, Samuel S., Salient Features of Electric Cooking, Electric Hot Water Heating and Electric House Heating. Columbus, Ohio, 1921. (From the Author.)

Yale University, Report of the President, 1920-1921. New Haven, Connecticut, 1921. (From the University.)

BOOK NOTICES.

La Matière et l'Énergie. Par Louis Rougier, Docteur ès Lettres. 8vo., xi-112 pages, paper bound. Price 9 fr. 50.

This is a new edition of the essay entitled " La Matérialisation de l'Énergie " which was rendered into English by Professor Masius as " Philosophy and the New Physics." This translation was reviewed in the issue of this journal for September last. In the present volume the author discusses the principle of relativity in some paradoxical relations, such as the attribution to energy of mass, weight and structure, and the view that matter is only a particular

form of energy. The old idea of a distinction between the ponderable and the imponderable gives place to the theory of an electromagnetic field or energy, of which radiation and matter are simple modalities, and a gravitational field or Einstein space. There is a brief bibliography the items of which are about evenly distributed between German and French sources with only one English reference. Being a French book there is, of course, no index.

                                                          HENRY LEFFMANN.

INDUSTRIAL AND POWER ALCOHOL. By R. C. Farmer, O.B.E., D.Sc., etc. 18mo., 106 pages, illustrations, bibliography and index. London and New York, Sir Isaac Pitman and Sons. 2s. 6d. net.

This compact and convenient volume contains a very large amount of carefully selected information on a most important industrial problem. There is perhaps no point in our present-day industrial development in which a more serious difficulty is met than in regard to the application of ethyl alcohol to manufacturing and power uses. Its beverage relations have always been a stumbling block to allowing its free manufacture, and the procedures of denaturization have only partially solved the problem. The advantages of alcohol for power purposes, especially in portable motors, both on sea and land are numerous. It is safer in the fire risk, is practically inodorous, more cleanly than the petroleum and coal-tar hydrocarbons, and is in unlimited supply, since the vegetable substances from which it can be obtained are easily grown, while the petroleum is a natural product which may become exhausted. Moreover, alcohol is of constant composition, while gasoline is variable. The question of cost is, however, the dominating one, and so far it has not been possible to bring down the commercial production of strong alcohol to a point at which it can actively compete with the ordinary motor fuels. It is also true that the usual form of engine is not satisfactorily applicable to alcohol, and one serious drawback is the comparatively low volatility of the latter. It is stated by Doctor Farmer that it is generally difficult to start an engine with alcohol, especially in cold weather, unless a preheater is employed for the carburetor, or a small amount of volatile hydrocarbon is first used. This mechanical difficulty may, however, be overcome if other drawbacks, especially cost, disappear. The book in hand gives a long list of raw materials from which alcohol may be obtained, but the existing literature shows that upon the question of cost no definite data are available. Denatured alcohol is now selling in the American market at about 40 cents a gallon, a price which places it wholly out of competition with " gas."

                                                          HENRY LEFFMANN.

INDUSTRIAL HYDROGEN. By Hugh S. Taylor, D.Sc., Associate Professor of Physical Chemistry, Princeton University. 203 pages and index, 8vo. The Chemical Catalogue Company, Inc., New York.

This is one of the series of monographs issued under the auspices of the American Chemical Society, the general conditions of which publications have been set forth in reviews of earlier numbers. The list of subjects to be treated in the series is quite large and comprehensive. The present work maintains the high character which was set by the earlier volumes, and covers a subject

in which chemistry and engineering are closely associated, but in which the principles of physical chemistry come much into consideration. So far as bookmaking is concerned the book is worthy of its text.

Hydrogen exists in the free state in nature in but a limited extent although abundant in combination. Air contains but very small amounts of free hydrogen, but some natural gases are richer. The occluded gas of meteoric iron consists largely of free hydrogen. Spectroscopic research indicates the existence of large amounts of free hydrogen in the sun, but it may be that in the intensely heated exterior of the sun, all chemical combination is abolished. For many years hydrogen has been used in both research and practical work. Shortly after the invention of the hot-air balloon, hydrogen was substituted, and has been much used, although coal gas has been also much employed. The oxy-hydrogen blowpipe was for a long while the only method for getting very high temperatures, and the lime light was an extension of this action.

For the preparation of hydrogen on a moderate scale, and especially when only occasionally wanted, the action of dilute sulphuric acid on iron offered a convenient method and was much used. The simplest method is by the action of steam on heated iron. This was brought out practically first by Lavoisier, who, in a paper presented to the Academy of Sciences in 1781, described the method and apparatus.

The older industrial uses of hydrogen did not usually require a gas of high purity, nor was the cost of production so important, but the newer applications require high purity and the operating cost is of moment. Among the important modern applications are the hydrogenation of oils and the manufacture of ammonia. For the former process several million feet of hydrogen are consumed every working day in this country. Perhaps the first importance is to be attached to the application in ammonia production. The now famous Haber process which was so successfuly operated in Germany during the war has necessitated a great development of hydrogen. The production of one short ton of ammonia involves the theoretical consumption of more than 82,000 cubic feet of hydrogen. When it is borne in mind that the full operation of the Haber plants in Germany is said to have yielded considerably over a million pounds of ammonia per day, the immensity of the consumption will be appreciated. It is stated on good authority that if these synthetic processes had not been brought to the efficiency they had, the war would have ceased in 1915, as the British blockade would have cut off very soon the supply of Chile nitrates.

Doctor Taylor sets forth many other uses for commercial hydrogen, some of which are naturally the outgrowth of the cheapening of the manufacture of it, due to the attention which has been paid to the subject.

The monograph covers very thoroughly the field and presents in clear and comprehensive form the leading methods of manufacture, with discussions of the chemical, physico-chemical and physical problems involved. Thirty pages are devoted to the testing for the impurities, from which we see that though the impurities commonly present are not numerous, most of them are highly objectionable. A glance at the index of authors shows that the field has been industriously investigated by the chemists and chemical engineers of all the principal countries. Many ingenious processes have been devised, but the bulk of the book is devoted to a few standard methods, among which the direct

decomposition of steam by chemical action is taken up first. The first patent is given as dated 1861, though this was long after Lavoisier had shown the practicability of the method. Extraction of the hydrogen of water-gas by liquefaction and the electrolysis of water are also given full attention. Illustrations and diagrams are liberally used and the work constitutes a most interesting and valuable contribution to one of the comparatively recently developed fields of chemical engineering.

HENRY LEFFMANN.

THE CENTENARY VOLUME OF CHARLES GRIFFIN AND COMPANY, LTD., with a foreword by Lord Moulton, and contributions by other collaborators.. 290 pages, 8vo. Charles Griffin and Company, Ltd., London.

This fine specimen of printing, with interesting essays by distinguished writers and scientists, commemorates the completion of a century of activity in the publishing business of the issuing firm. The house started in Glasgow, and was for some time publishers to the University. Griffin's Public Library was organized in that city, and a cut of the original building is given as frontispiece. Many portraits and illustrations of buildings are included. Some of these bring us back to the early days of the 19th century, in the hot youth of the western republic when George the third was king and James Monroe, president, about the time when Alexander of Russia, that curious mixture of mysticism and despotism, was trying to bring peace to the world by the Holy Alliance, a scheme that failed completely.

The individual essays relate principally to the publishing activities of the firm during the century of its existence, and the table of contents indicates how wide that field has been, though limited to books of useful and educational character. As a specimen of printing and press work it is excellent and the photogravures are in the best modern style.

HENRY LEFFMANN.

LA PHYSIQUE THÉORIQUE NOUVELLE. By Julian Pacotte, D.Sc., with a preface by Emile Borel. 8vo., 179 pages and contents. Paris, Gauthier-Villars et Cie. Paper bound, 12 francs, net.

This work comprises within moderate compass and without mathematical methods a collection of the theories which constitute the new theoretical physics. This science has for origin the electrodynamic principle of Lorentz, the defined form of that of Maxwell. The more advanced theories are due to Einstein. They relate to relativity, the energy equivalent of two material masses, the atoms of energy. Among the innumerable questions that arise from this view, two points seem particularly important. The first of these is that of the relations between continuity and non-continuity. Emile Borel has developed this subject. Riemann observes very justly that all our observations (based on the theory of the existence of rigid solid bodies) prove that space is in the mean closely approximate to the Euclidian form. These observations are less delicate than those by which we can prove that a polished metallic surface is flat. We know that in the case of the metallic surface there is only an appearance of flatness. An enlargement will bring out numerous irregularities. On a different scale, we know that the surface of the ocean is, in the mean, sensibly spherical in spite of irregularities. The second point is the

new conception that there is set forth, more and more, a theoretical physics wholly analogous, by its methods, to geometry.

The author hopes that this book will serve to direct the interests of many younger workers to theoretical physics in which the work to be accomplished is great, and requires the coöperation of the scientists of all countries, each one carrying out the labor according to his particular culture.

HENRY LEFFMANN.

A COAL MANUAL FOR SALESMEN, BUYERS AND USERS. By F. R. Wadleigh, Member, American Institute Mining and Metallurgical Engineers. 18 mo., 178 pages and index. National Coal Mining News, Cincinnati, 1921. Price $2.50.

Within very small compass this book contains a large amount of interesting and important matter. The coal question is a very important one and the householder is as deeply interested in it as the larger user. The subject matter is included under nine chapters and a bibliography. A brief allusion to history is made, and some account given of the origin of the material. General statistics of the occurrence of coal are furnished. A chapter on coke is included and practical directions as to the use of fuel in power plants. Interesting information is given as regard spontaneous combustion in stored coal. Several pages are devoted to the consideration of pulverized coal, the opinion being decidedly favorable to this form.　　　　HENRY LEFFMANN.

LA LOI DE NEWTON EST LA LOI UNIQUE. By Max Franck. 8vo., 156 pages and contents. Paris, Gauthier-Villars et Cie.

Thoughts in regard to time and space have engaged the attention of scientists from a remote period, and Einstein's revolutionary theories have intensified modern interest in the subject. France has apparently taken the question much to heart and sharp discussion has followed the promulgation of the theory of relativity, with the result that intellectual Gaul is now divided into two parts, one hotly defending Einsteinism and the other as hotly opposing it. The present work is a contribution from the latter side, in which the author examines the mechanics of space assuming that all potential energy resides in the absolute void of the physicist, and that all matter is constituted by a unique element of inertia, mobile in the void.

The first consequence of the author's examination of the data is the confirmation of the Newtonian formula, which the announced law will give an exact interpretation, for which reason the author has chosen the specific title of his work. The theory thus applied utilizes only the ideas of space, time, force and inertia included in Euclidian geometry and in rational mechanics.

HENRY LEFFMANN.

NATIONAL ADVISORY COMMITTEE FOR AERONAUTICS, Report No. 115, Bending Moments, Envelope, and Cable Stresses in Non-Rigid Airships. By C. P. Burgess. 14 pages, illustrations, quarto. Washington, Government Printing Office, 1921.

No simple but comprehensive method of calculating the principal stresses in the envelope of a non-rigid airship has hitherto been described and published in the English language. The present report describes the theory of the calcula-

tions and the methods which are in use in the Bureau of Aeronautics, United States Navy. The principal stresses are due to the gas pressure and the unequal distribution of weight and buoyancy, and the concentrated loads from the car suspension cables.

The report deals also with the variation of tension in the car suspension cables of any type of airship, with special reference to the rigid type, due to the propeller thrust or the inclination of the airship longitudinally.

PUBLICATIONS RECEIVED.

Essai Philosophique sur les Probabilités, par Pierre-Simon Laplace. 2 vols., 16mo. Paris, Gauthier-Villars et Cie., 1921.

Memoires sur l'Electromagnétisme et l'Electrodynamique, par André-Marie Ampère. 110 pages, illustrations, 16mo. Paris, Gauthier-Villars et Cie., 1921.

Cours de Mécanique Rationelle a l'Usage des Élèves de l'Institut Électrotechnique et de Mécanique Appliquée et des Candidats an Certifical des Mathématiques Générales, par Louis Roy. 259 pages, illustrations, 8vo. Paris, Gauthier-Villars, 1921. Price 25 francs.

Cours complet des Mathématiques Spéciales, par P. Haag. Tome II, Geometry. 661 pages, illustrations, 8vo. Paris, Gauthier-Villars, 1921. Price 65 francs.

Canada Department of Mines: Mines Branch Bulletin No. 33, Gas Producer Trials with Alberta Coals [Supplementing Report No. 331] by John Blizard and E. S. Mulloch. 40 pages, diagrams, 8vo. Ottawa, Government Printing Bureau, 1921.

U. S. Bureau of Mines: Eleventh annual report of the Director for the fiscal year ended June 30, 1921. 133 pages, diagrams, 8vo. Monthly Statement of Coal Mine Fatalities in the United States, September, 1921, by W. W. Adams. 11 pages, 8vo. Technical Paper No. 248, Gas Masks for Gases Met in Fighting Fires, by Arno C. Fieldner, Sidney H. Katz, and Selwyne P. Kinney. 61 pages, illustrations, plates, 8vo. Washington, Government Printing Office, 1921.

National Advisory Committee for Aeronautics: Technical Notes, No. 66, Göttingen Wind-tunnel for Testing Aircraft Models, by L. Prandtl. 20 pages, plates, quarto. No. 67, Ground Influence on Aerofoils, by Arthur E. Raymond. 8 pages, plates, quarto. No. 68, Vortices and the Related Principles of Hydrodynamics, by A. Betz, Göttingen. 22 pages, plates, quarto. No. 69, An Investigation on the Effect of Raked Wing Tips, by F. H. Norton. 2 pages, plates, quarto. No. 75, Effects of Varying the Relative Position of Wing and Fuselage, by L. Prandtl. 4 pages, plates, quarto. Washington Committee, 1921.

CURRENT TOPICS.

X-ray Analysis of Three Series of Alloys. MARY R. ANDREWS. (*Phys. Rev.*, Sept., 1921.)—The diffraction patterns resulting from the passage of X-rays through crystals are gradually laying bare the intimate structure of both elements and compounds. The method has now been applied in the research laboratory of the General Electric Company to the study of alloys. Fine filings of the alloy were mixed with collodion or zapon and pasted upon a thin sheet of glass. The diffraction lines produced when a narrow beam of X-rays traversed the layer were recorded photographically.

In the cases of nickel-iron alloy the structure is centered-cubic alone from pure iron up to a content of 22 per cent. nickel, from 30 to 100 per cent. nickel the structure is face-centered cubic alone. For intermediate percentages both types of structure exist in the same specimen. An interesting connection between structure and magnetic properties seems to be indicated as an outgrowth of experiments on a particular alloy entirely non-magnetic at room temperature, but showing magnetic properties after having been chilled by liquid air. After the treatment there was a distinct development of the centered-cubic structure which was wanting in the non-magnetic state. A Heusler alloy likewise gave a centered-cubic form.

Zinc-copper alloys have a far more complicated structure. There are ranges of composition where they are face-centered cubic or centered-cubic, rhombohedral or hexagonal, with combinations for for intermediate compositions.

This pioneer work opens up a new field of investigation in the important matter of alloys.

G. F. S.

The Reception of Wireless Waves on a Shielded Frame Aerial. A. A. CAMPBELL SWINTON. (*Phil. Mag.*, Oct., 1921.)—The experiments here recorded were undertaken to test a suggestion that it might be worth while to see whether direction-finding properties for wireless waves would show themselves in an arrangement made by placing a frame aerial inside of a metal tube or wire spiral open at both ends. The investigation was carried out at London using the waves from the Eiffel Tower, in Paris, with the wave-length of 2600 metres.

A wooden frame, $1\frac{1}{2} \times 1\frac{1}{2} \times 4$ feet in length, was wrapped spirally with copper wire to form the shielding tube. Within it was put the frame aerial. The latter gave as strong signals as when it was outside the tube, so long as the ends of the square wire spiral were not connected with each other. Upon connecting them, however,

the signals dropped to 50 per cent. of the former strength. The presence or absence of grids of wire, closing the ends of the tube and connected to the spiral, made no difference. Furthermore it made no difference in what direction the tube itself pointed so long as the plane of the frame pointed to Paris. Enclosing the tube, ends as well as sides, with iron wire netting reduced the strength of the signals, but wrought no change in the failure of the combination to show the direction along which the waves were coming, except in so far as the frame alone did this.

The aerial frame with the telephone receiver and other auxiliary apparatus was placed within a cube of sheet copper, connected to earth. The audible signals were conveyed to the ear outside of the cube by means of a rubber tube. The cube was left open on one side. When this open side was toward Paris and the frame properly pointed the intensity of the signals was estimated to be 5 per cent. of that given with no shielding for the frame. Upon gradually closing the open sixth side the strength of the signals diminished but never entirely ceased to be audible until the metal of the lid made contact with the metal of the rest of the cube. With the box tightly closed no signal whatever could be heard. Exactly the same results were got when the open side of the cube pointed away from Paris. Tin-foil pasted on wood acted just like a sheet of copper for the lid of the box. This calls to mind Faraday's famous room covered with tin-foil within which there were no electrostatic effects observable.

G. F. S.

Centennial of Photography.—*La Revue Française de Photographie* is preparing to celebrate the hundredth anniversary of the discovery of photography. A contributor asserts in a recent issue that the first step in the art was made by Niépce in 1822. The formal announcement of Daguerre's method was made before the Academy of Sciences by Arago in 1839, and this date has been generally regarded as the initial one, for which reason a celebration of the semicentennial was held in 1889. Frenchmen have strong tendency to claim French initiative in every field of photographic work, and are especially antagonistic to claims made in Germany for priority, but it does appear that there is some basis for such claim, inasmuch as a German investigator did make some pictures early in the 18th century by taking advantage of this method. Other workers contributed to the early development. Charles, a Frenchman, made silhouettes in the latter part of the 18th century, and Davy and Wedgewood also obtained simple pictures in 1802. It appears that Niépce made most important advances, but his work did not attract wide attention, and it was left for Daguerre to develop an entirely new method and to place photography on a practical basis.

H. L.

Production of Furfural from Corn-cobs.—Furfural is a hetero-cyclic aldehyde which is used as a reagent to detect the presence of certain compounds such as indol and the bile acids. It is also used in the synthesis of certain dyes. Usually it is prepared by the distillation of bran with hydrochloric acid. F. B. LA FORGE (*Jour. Indus. Eng. Chem.*, 1921, xiii, 1024–1025) has devised a method for the production of this aldehyde by heating corn-cobs with water under pressure. The process is conducted at a temperature of 180° to 185° C. in an autoclave, which is provided with a condenser, through which the evolved vapors pass and are condensed, as the pressure is released. Several successive portions of corn-cobs may be extracted with the same portion of water; the insoluble residue of cellulose is removed from the autoclave before the next batch of cobs is added. Each batch is heated under pressure for 45 minutes. The solution obtained from the corn-cobs is heated in the autoclave for 15 minutes at the temperature stated; then the pressure is released; a volume of water equal to the volume of the condensed liquid is added to the contents of the autoclave; and the entire cycle is repeated several times. Furfural is present in, and is recovered from the condensed liquid. The yield of furfural is approximately 7.75 per cent. of the weight of the corn-cobs used. The process may be simplified by omission of the removal and saving of the cellulose; however, the latter is a valuable by-product.

<div align="right">J. S. H.</div>

The Luminosity of the Night Sky.—CH. FABRY has a short article on this subject in *Scientia*. Newcomb was the first to draw attention to the matter, and said " The total quantity of light coming from the aggregate of stars may serve to control our theories of the universe. It seems possible to determine not only the total value of this emission, but also values from each part of the sky. The quantity should be considered as a constant basic value in astronomy." The problem is to determine the total emission and also the intrinsic emission of each area of the sky. Newcomb made a rude attempt in this direction.

Fabry says that, omitting some discordant results, the brilliancy of a given point in the sky seems to be constant. Different areas are not in agreement with each other, but the differences are less than might be supposed. In the Milky Way the most brilliant portions are about double the luminosity of the less brilliant. The general light of the sky is the influence that prevents us from seeing distinctly stars below the 6th magnitude. If the background was without luminosity, stars as low as the 8th magnitude could be seen. This source of the light cannot be referred to the stars which are individually indistinguishable. Several suggestions are offered as to the possible source of this general luminosity, but no experiments or observations on the subject are reported in the paper.

<div align="right">H. L.</div>

Some Factors Affecting the Resistance of Sputtered Platinum Films. L. R. KOLLER. (*Phys. Rev.*, September, 1921.)—As soon as a film of the metal is formed by sputtering from the cathode its electrical resistance commences to change. If the film is kept in a high vacuum, at first the decrease is rapid, then it becomes slower and at the end of 12 hours it is negligible. In one case the initial resistance was about 1400 ohms and the final amount was one-third of this. In the freshly deposited film the resistance must consist of two parts, one the resistance of the metal itself and the other the resistance due to the contacts between the particles constituting the film. The diminution of the total resistance is ascribed to the coalescing of the particles with a consequent lessening of the contact resistance. Anything that hinders the union of the particles should make the change of resistance slower. When air is admitted to the film at first a slight rise in the resistance takes place. After this there is practically no change in the resistance. What probably takes place is this: As soon as the air comes into contact with the metal the latter becomes covered by an adsorbed layer of air, which forces the particles apart a little and thus increases the resistance. Subsequently no further coalescence of the particles can occur owing to the layer and the resistance remains constant. When the air is pumped out the aging process resumes its course. Oxygen is far more effective in modifying the decrease in resistance than are nitrogen and carbon dioxide. In this connection it was found that the sputtering process renders the platinum of both the cathode and the film active so that it causes oxygen and hydrogen to unite at room temperature.

The temperature coefficient of the films is smaller than that of the metal in one piece. The increase of temperature makes the genuine resistance greater but this change is opposed by the reduction in resistance brought about by the coalescence favored by the higher temperature.

G. F. S.

New Specific Heat Apparatus. EZER GRIFFITHS. (*Proc. Phys. Soc. London,* August 15, 1921.)—The usual methods of measuring specific heat manifestly do not apply to such substances as cork, charcoal, slag wool and diatomaceous earth, yet these are of technical importance on account of their low heat conductivity which is the very property rendering it difficult to determine the specific heat.

The substance was first reduced to a fine powder. This was then placed in a hollow aluminum cylinder until the latter was less than half full. On the inside of the cylinder were fins to stir the powder up. Besides these the cylinder contained a stationary coil, heated by the electric current, and several thermo-junctions for the measurement of temperatures. The cylinder was rotated and the current passed through the heating coil. The heat there developed goes to raise the temperature of the powder swirling through the coil and

also of the cylinder and its contents, for which a correction can be made. Loss of heat by radiation is obviated by surrounding the cylinder with a copper drum wound with a heating coil. By this means it was possible to maintain the temperatures of the drum and of the cylinder the same, so that no exchange of heat between them took place.

The temperature of the powders was raised through only fifteen degrees in order to avoid changing the moisture content during the experiment.

The following values were found for the specific heats—charcoal, 29; slag wool, 17; diatomaceous earth, 23; cork, whether slab or granulated, 43.

<div align="right">G. F. S.</div>

Gas Masks for Fire Fighters.—The success of the U. S. army gas mask, which at the close of the war had been developed to a satisfactory protection against all the gases met on the battle-field, led to a hasty judgment that it might be used as a protection against the products of combustion in mines, common fires and some industrial products, but this is not the case. Some misleading statements were made by advertisers who had masks for sale. Experience showed that the army masks do not protect against the ordinary products of combustion, which are largely carbon dioxide and monoxide. Neither of these was an important ingredient in the offensive war gases, yet they are both capable of causing suffocation. Moreover, in a notable percentage of cases, the suffocating effect is not due to the introduction of any poisonous gas, but to the diminution of oxygen, and it is obvious that no mask can protect against such condition.

Technical Paper No. 248 of the U. S. Bureau of Mines, a pamphlet of over fifty pages, gives the results of many experiments and investigations for ascertaining the proper material for masks for miners and firemen. In some cases, indeed, army masks have served a good purpose, one instance being a fire in a waste-paper plant. The army mask gives no protection against ammonia, which is important in view of disasters at refrigerating plants, and the frequency with which small refrigerating plants are attached to other industrial establishments. The gases commonly encountered in fires and other accidents in civil life have been carefully studied by the authors of the bulletin, Messrs. Fieldner, Katz and Kinney. The composition of the most important absorbents is given, but it appears that no satisfactory absorbent for carbon monoxide is yet obtainable. Some progress has been made in the matter, however, and it is expected that a satisfactory absorbent may before long be found. This gas is one of the most dangerous in the list, because it is a common product of imperfect or choked combustion and is also present in large amount in common illuminating gas. In fact, it is responsible for more deaths in civil life than all other gases combined.

<div align="right">H. L.</div>

The Muscle Shoals Plant.—This great plant located on the Tennessee River was erected as a war industry for the purpose of nitrogen fixation. The portion designated as No. 1 was arranged to operate a modified Haber process, while a much larger installation, No. 2, operated the cyanamid method. No. 1 had not been carried beyond the experimental stage when the war closed, and further work was discontinued. No. 2 is complete and has a capacity of 110,000 tons of ammonium nitrate per year. All work, however, has been suspended as well as on the great dam, which was to utilize the water power of the stream. It is stated that the dam as planned will furnish water enough to develop 600,000 horsepower. The Mississippi Valley Association, at its meeting in May last, appointed a committee to bring to public notice the facts about this plant, and the committee has lately issued a report in pamphlet form with illustrations. The following are some of the conclusions reached:

That two nitrate plants, of large capacity, well built at great expense, and required for national defense are standing idle.

That these plants can be made a profitable investment and a benefit to agriculture if cheap power is available.

That this cheap power can be furnished only by the dam, now awaiting completion.

That in its present condition the dam blocks navigation on the Tennessee River.

That the work done to date has been well done, but will certainly be damaged if abandoned in its present condition.

That additional delay means only a constantly increasing loss to the Government.

That a relatively small additional cost will bring to fruition a great enterprise, and add an important factor to the development of our country.

That the completion of this enterprise is one of the most important factors before us at this time and in accord with the declaration of principles of our Association which calls for the development of agriculture, of industry, of finance, and of transportation.

In view of the fact that the Government can not transfer its right to manufacture nitrate by the cyanamid process to others than the patentee, a government controlled corporation or corporations should be established to operate both the hydro-electric power and the nitrate plants, preference being given to agriculture, but always reserving the right to resume control and operation in event of war.

STUDIES ON LIQUID FILMS.*

BY

SIR JAMES DEWAR, LL.D., D.Sc., F.R.S.

Fullerian Professor of Chemistry, Royal Institution; Honorary Member of the
Institute; Franklin Medalist, 1919.

SOME problems presented by liquid films were discussed in the Discourse of 1917 [1] and in a contribution to this Journal.[2] These studies have been continued and further developed in the restricted time left for research after meeting the demands of the Government departments; but such conditions imply a certain amount of discontinuity which cannot but leave its mark on the inquiry.

BUBBLES FOUR FEET IN DIAMETER.

In order to increase the size of bubbles above those described a year ago (46 cm. in diameter), advantage was taken of a cool cement-lined cellar (some 600 cubic feet capacity) which was so fitted that the nozzle and blowing tube were passed through the door and controlled from outside. All apertures and cracks were filled with glycerined cotton wool. The atmosphere of the cellar was several times cleaned and renewed by pumping in purified air, but no permanent purity could be maintained. In less than two

---

* Communicated by the author. Lecture delivered before the Royal Institution, January 18, 1918, and later to appear in its Proceedings.
[1] "Soap Bubbles of Long Duration," *Proc. Royal Institution*, vol. xxii, 179.
[2] "Soap Bubbles of Long Duration," vol. 188, p. 713.

days the Tyndall cone would reappear. Large sheets and trays smeared with glycerin were of no assistance in reducing the mist, so that although bubbles up to four feet in diameter were obtained, they did not last above a few hours.

PLANE BLACK FILMS 2500 SQ. CM. IN AREA.

At the Discourse given a year ago a stoppered vessel was shown which contained a plane black film 19 cm. in diameter; the film was then one week old, and has remained unchanged to this date.

Fig. 1.
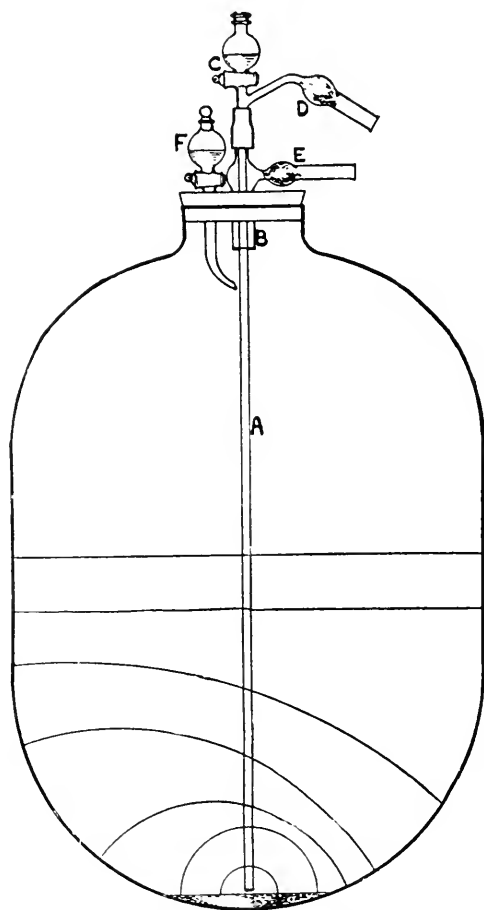
For the purpose of extending the study to larger films, the cylindrical globes that were used last year for the examination of 40 cm. bubbles were employed. Plane films 56½ cm., or nearly two feet in diameter, were thereby obtained which lasted for 40 days, and even more, after becoming entirely black. Fig. 1 shows a globe fitted for this purpose. About half a litre of soap solution having been run in, and the end of the tube A dipped into it, a

bubble, blown by pure air, was started and gradually expanded, as shown by the various stages of the diagram, until it became a plane horizontal film about the middle of the vessel. Some idea of the appearance of the film in the globe can be gathered from Fig. 2, reproduced from a photograph taken with a white screen placed behind and a little above the film, thus reflecting diffused light.

The globe and its fittings must be scrupulously clean, and the interior free from all traces of floating matter when tested by the Tyndall cone of light. By careful manipulation the soap solution was made to flow all over the inside, while the tube A was also

FIG. 2.

wetted by a stream of soap solution from a dropping funnel F fitting tightly in the rubber cork used to close the neck of the globe. The tube A can slide freely up and down in the support tube B, to which was sealed the bulbed outlet E. The upper part of A could, on occasion, be fitted with a dropping funnel C, sealed to the vertical portion, while still connected to the bulbed nozzle D, by which pure air was admitted. The bulbs D, E were loosely packed with cotton wool moistened with glycerin. C was only used when subsequent additions had to be made to the soap solution in the globe.

After the plane film was obtained in the right position midway in the globe, A was raised until its lower end was a few inches below the film. The nozzles D and E were open, but were provided with soda-lime guard tubes, so that the spaces above and below the film were equally open to the atmosphere, though guarded from contamination. This ensured that the fluctuations of the atmosphere were equalized throughout both portions of the relatively large space of the globe; otherwise the film was not likely to last long because of the vertical displacements that would occur. In one case a barometric alteration of 1 cm. in 20 hours caused the film to move through 5 mm. After the globe has

drained for a day or two, there is not enough liquid left on the walls to keep the film sufficiently lubricated to allow of such oscillations. The only liquid available is in the tiny channel—the Gibbs layer—round the periphery of the film. This channel is roughly triangular in section, with the base of the triangle on the glass walls, and the concave sides converging to the film which extends out beyond the apex of the triangle. In a very well-drained film the base of this triangle may not be more than 0.1 mm., so that the sectional area of the channel is about $\dfrac{1}{20,000}$ th of a sq. cm. The total liquid available round such a film 56 cm. in diameter is, therefore only about 1 cgm. It is obvious that long before such complete drainage as this is reached any movement of the film occurring over a relatively dry surface will quickly exhaust the liquid in the channel, and the film will be ruptured. However, when the proper precautions were taken, the displacements due to atmospheric variations did not amount to more than 1 or 2 mm. for weeks together.

Until they become completely black very striking color effects can be seen in these large horizontal films. They have of course only a small gradient of thickness, so that the bands of color are drawn out into large areas. During this period convection in the films is most easily seen, because of the brilliant contrasts afforded by the moving portions. Should there be much fluctuation of temperature, the complete development to the black state may be arrested, the last part of the colored area being kept in intermittent circulation for several days. Superfluous liquid draining down outside the central tube will produce a similar result by becoming spread out on the black film surface as a colored clot round the tube. When this clot grows sufficiently it will draw off slowly, and pass down the radius of greatest inclination of the film. It formed on one occasion an ellipse (1 cm. by 1½ cm.), which took 35 seconds to traverse the last one-fourth of its path. On approaching the periphery where the film curves up slightly into contact with the glass, the clot flattened out and curled into the most intricate convolutions, finally sweeping round close to the edge, a writhing mass of colored streaks, many of which became roving stars on the black film. The whole colored area was finally drawn into the Gibbs ring, from which frequent escapes of small drops of liquid took place.

A favorable condition for longevity is a quiet temperature

rather below 10° C. Sudden alterations of 3° or 4° C. are most likely to burst the films by provoking too rapid convection therein, as is evidenced by very rapidly moving streams of silvery stars drawn from the Gibbs ring.

The vibrations which occurred during the operation of the air compressors in the laboratory did not affect the final stability of

FIG. 3a.
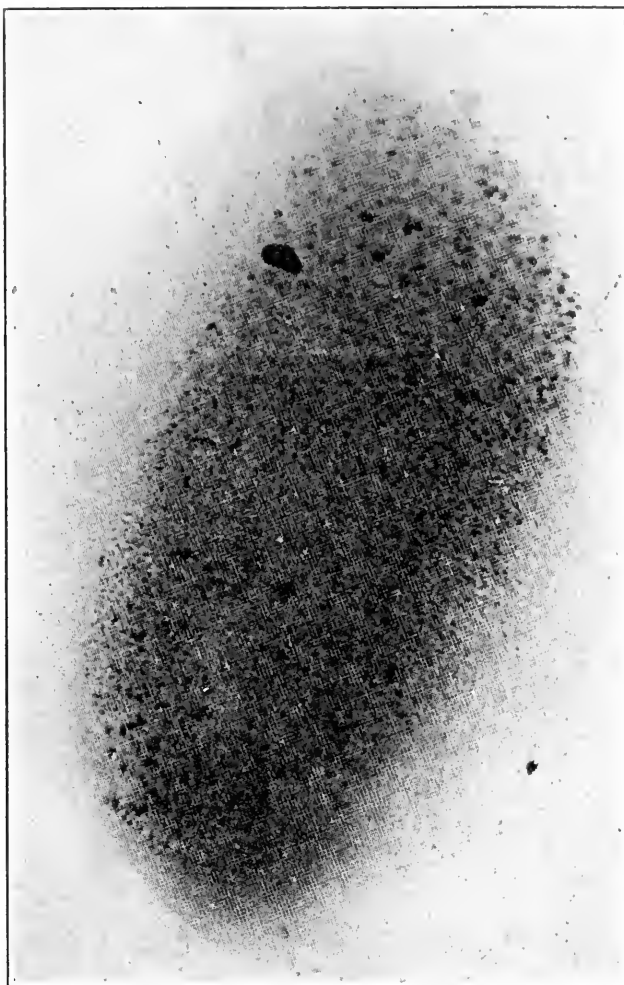
the black films. A stationary circular wave was produced having an amplitude of over 1 mm. vertically all round a circle midway between the central tube and walls of the globe. This motion continued the whole time the machines were working, but the films always survived.

Instead of having one large plane black film, a mesh-work of black films can be obtained completely filling the globe. To pro-

duce this, the lower end of the blowing tube A (Fig. 1) is inserted slightly below the surface of the soap solution. The air current being regulated suitably to the diameter of the tube A, a steady succession of uniform bubbles is produced. The surface of the glass having previously been well moistened, the issuing bubbles

FIG. 3b.
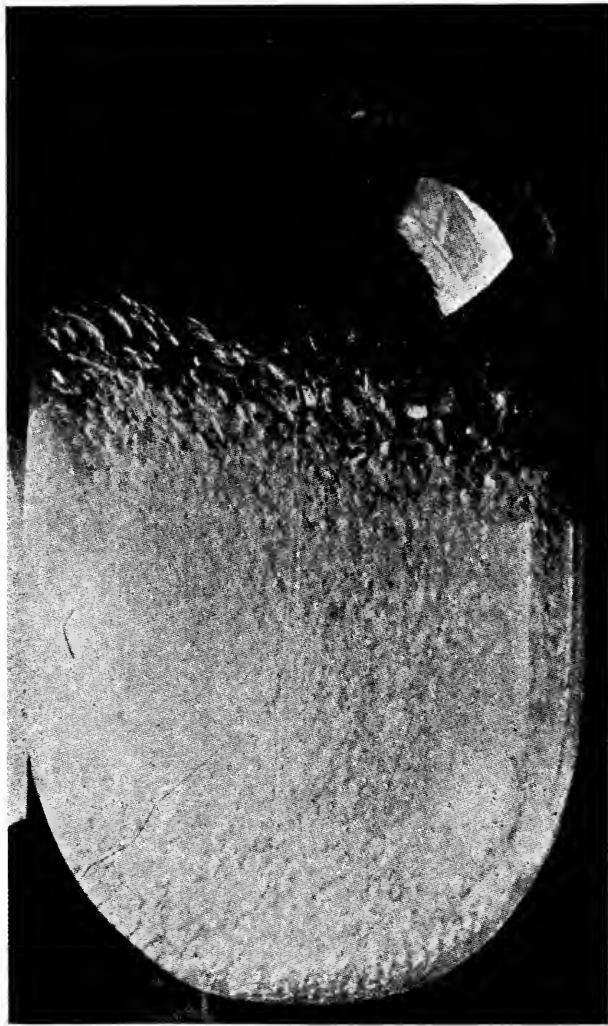
consequently encounter little resistance, and develop rapidly, linking up into a glittering lustrous froth which increases until the globe is full. Excess liquid drains away very rapidly, the black stage being reached in about an hour. The beauty of the mass can be seen properly only when a beam of light is flashed upon it in continually changing directions, the different inclinations of the

internal plane films giving rise to a continuous series of brilliant scintillations (Fig. 3*a*). The same appearance is perhaps still more remarkable when the mesh-work is lit up by diffused light from rays thrown across the observer's line of vision (Fig. 3*b*). A black background is used in both cases.

The internal walls of the various cells being plane polygons, the pressure of the air in these cells is the same for all, and is regulated according to the curvature of the cell-walls on the outer boundary. As transference of the enmeshed air from the mass can take place only through the curved boundaries of the outer layer of bubbles, contraction of the mass from this cause is relatively slow. In one case it required a fortnight for the initial volume to be reduced to one-half.

FIG. 4.

To obtain the best result the blowing tube A should be withdrawn when the mesh-work has been completed, as it exerts some protecting power over the bubbles that closely surround it, thus causing an annular depression farther out, and tending to destroy the mass.

COLUMNS AND CHAINS OF BUBBLES.

For the purpose of studying bubble clusters and film complexes, instead of single bubbles and plane films, an arrangement of the nozzle was employed, by which it was possible to get a succession of bubbles of any required volume, linked together, in one operation. The apparatus employed is shown in Fig. 4. A is a stoppered reservoir of soap solution from which a capillary tube passes down the air-supply tube D, B, to about 1 cm. above a constriction K. After passing K the lower end of the air-supply tube is, for convenience, fitted by a ground joint to an enlarged nozzle C, securely held in position by the rubber cork E. The stopper A being opened at regulated intervals of time a series of drops falls on the constriction K, which are immediately blown into films by the constant air current entering through the bulb D (protected as before by lightly packed glycerined cotton wool). Hence a series of bubbles is produced at the nozzle C, which may have equal or
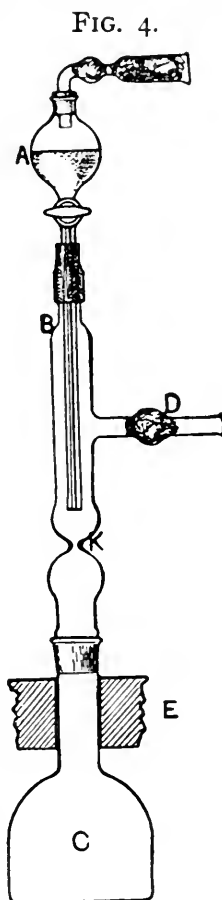
different volumes as desired, and may be further controlled so as to present themselves either as a vertical column or as a cluster.

The shape of the cluster obtained depends on the dimensions

Fig. 5.
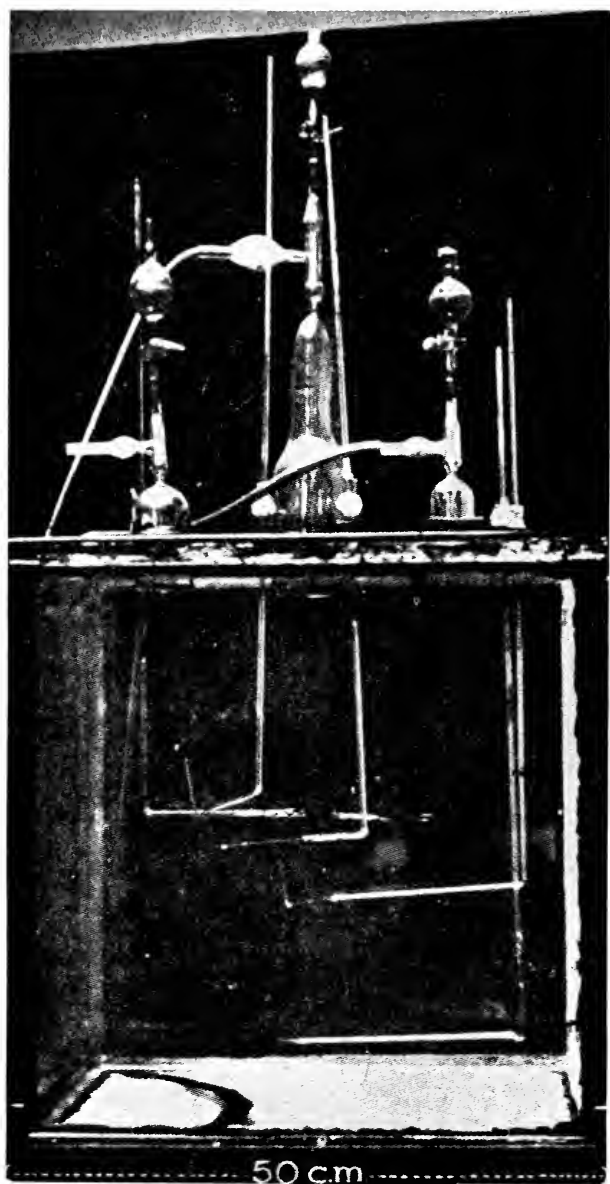
Fig. 6.
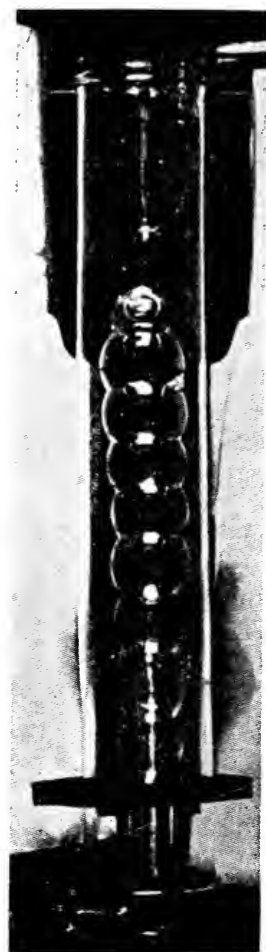
of the nozzle, the speed of the air current, and the relation between the mass of the drop and the size of the constriction. If the drop be too large or the air current too slow, extra films result from the accumulation of superfluous liquid; the same thing happens with an enlongated constriction. On the other hand, too rapid a current

may simply spray the liquid over the interior of the nozzle. The cleanest working is obtained from a short neck blown out above and below in a spherical shape as shown in the figure at K.

A succession of equal bubbles may either form a regular cluster on the mouth of the nozzle, or a vertical chain or column of spherical segments united by plane circular films. A cluster will usually be formed when the bubbles are less in diameter than the nozzle, and a chain or column when the bubbles are larger. For the manipulation of these complexes an air-tight, cubical, plate-glass chamber was made (Fig. 5.), on a frame of aluminum alloy (edge, 50 cm.). The glass plate for the top was 1 cm. thick; holes were cut in it for the rubber corks that held the nozzles and supported the movable glass rods which carried the different small pieces of apparatus used to catch and control the chains while being formed.

For the manipulation of the longer columns the glass cylinder shown in Fig. 6 was used. It was 3 feet long and 6 inches in diameter; its ends made air-tight joints with two plates, the upper of which held the blowing nozzle, while the lower held a support ring. Suitable exit stopcock and soda-lime guard tube were also fitted. The support ring was sealed to the top of a vertical rod that could slide up and down in an air-tight joint in the bottom plate. The cylinder was fixed on a shelf in the middle of a massive wooden stand, and a hole was cut in the shelf to allow free movement to the sliding rod. When a to-and-fro motion was given to the support rod, the flexibility of the column was readily seen; transverse waves appeared to pass up the whole length, each segment moving on the one adjacent as if attached by a very free universal joint. By drawing the rod down a considerable extension could be obtained; contrariwise by raising it a bulging or spiral formation would result. If this be carried further and the surface be sufficiently moist, the column will sag out into contact with the glass walls and form a chain of oval segments. In a wider vessel, however, the segments can in this way be linked up successively to form regular clusters.

A beautiful exhibition of multiple scintillating colored reflections is obtained when a beam from an arc lamp below is directed up through the column while the support rod is moved. An even more complete illumination is secured by using a white lined hood above, in which is hidden a 200-watt lamp, with two white

wings of stiff card fixed one on each side of the central black stand.
These side screens alone are sufficient for this purpose if the whole
apparatus stands in a good light.   A striking contrast is obtained
when the column is drained to blackness and illuminated by a
beam from below, if an occasional drop of soap solution is allowed
to trickle down through the nozzle. Before this is done very little
is seen except the bright point reflections from the curved surfaces;
but, as the falling drops arrive in rapid succession at the planes
between the adjacent segments, the thin circular channels flash

FIG. 7.
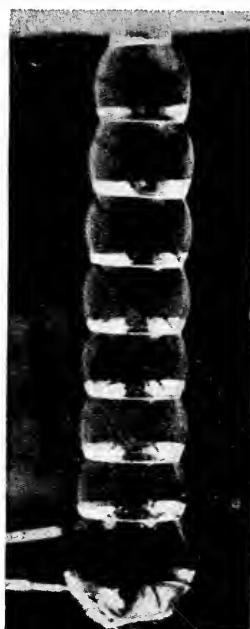
up into sparkling silvery light from the internal reflections of the
accumulated liquid.   Fig. 7 gives some idea of the appearance.

The following particulars show how some of the results
were obtained:

(a) Nozzle, 3 cm. diameter; constriction, 1.15 mm. bore;
drop, 18 mgms.; air current approximately 500 c.c. a minute; drop
interval, 5 seconds; giving a volume of 42 c.c. for each segment.
While they were being blown the free end was caught on one of the
movable glass rings already mentioned, by means of which fifteen
bubbles were steadily drawn out into a flexible catenary with its
ends 13 cm. apart (Fig. 8).

(b) Nozzle, 3.4 cm. diameter; air current, 565 c.c. per minute;
drop interval, 7½ seconds; giving a volume of about 70 c.c. for

each segment.   A column of eight of these bubbles reached from the rim of the nozzle to the wet floor of the cube, where contact was made.   The same nozzle could give a chain of nine bubbles of three times this volume.

(*c*) Same nozzle; air current, 305 c.c. per minute; drop interval, 9½ seconds; giving a volume of about 48 c.c. for each segment. A column of ten of these bubbles was held on a fairly

FIG. 8.
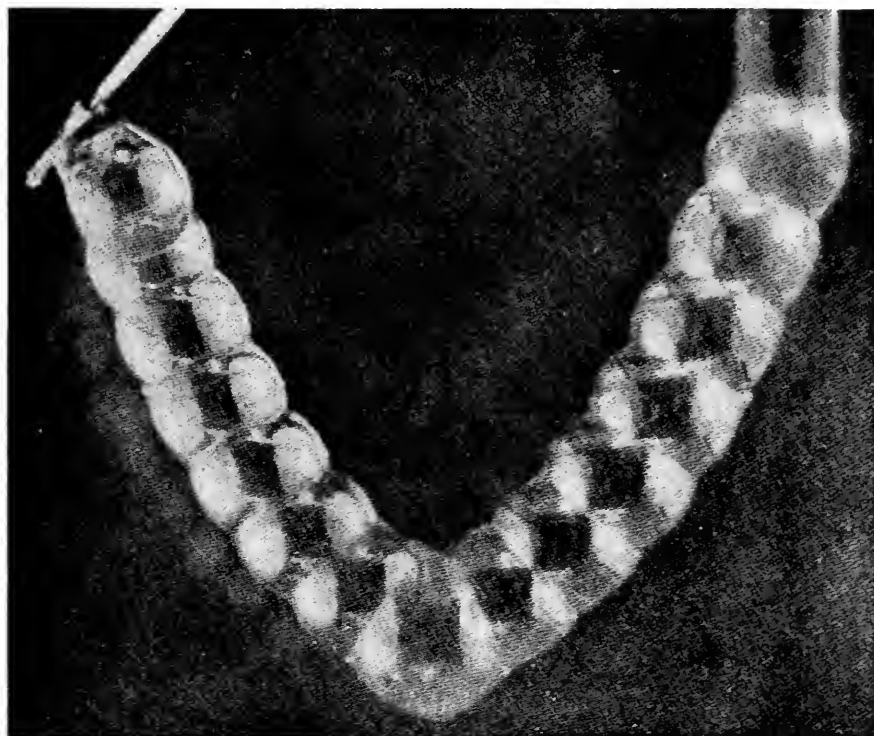
straight axis inclined at about 50° to the horizontal after they were drained free of excess liquid.

Some of these chains are liable to break with excess liquid (Fig. 8). This can be largely obviated by using a percentage of hydrogen in the air current, provided an atmosphere of pure air is maintained in the glass cube. The buoyancy of the bubbles is thereby increased for a time sufficient to allow the column to be manipulated. When the chain has once been secured any further accumulation of liquid must be continually removed. For this purpose a fluted glass rod some 2 mm. thick and 3 or 4 cm. long was very effective. (It was made by drawing out a bundle of seven small glass rods in the blow-pipe, and was utilized by attach-

ment to one of the movable bent glass rods passing through the top of the cubical box.)

When very large bubble segments are required it is safer to interrupt the air current between two adjacent segments, while a
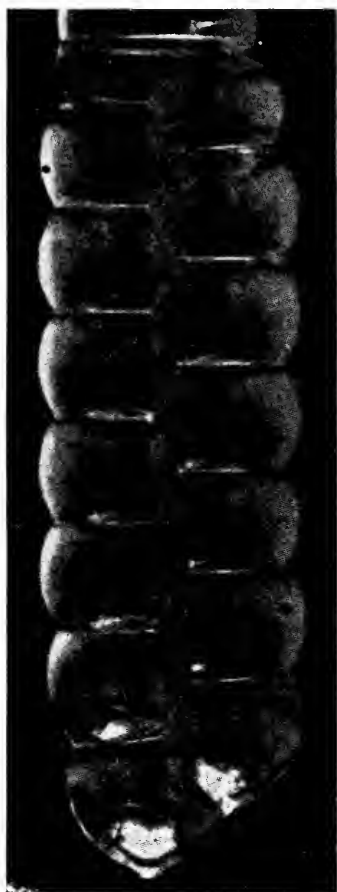
Fig. 9.　　　　　　Fig. 10.

few extra drops of liquid are run in to remoisten the glass surfaces. In this way bubbles of over 1 litre were obtained on a nozzle 5 cm. in diameter, with a constriction of 1 mm. bore, and a 25 mgm. drop. Four of these linked together and forming a chain inclined at about 45° to the vertical were photographed on a Lumière autochrome plate, which, in addition to the colored contours, showed clearly the brilliant bands on the plane films between the equal segments. To obtain these photographs the cubical glass vessel was

placed in full sunlight.   The top and two opposite sides were covered with thin tissue paper to give uniform diffuse illumination. Black paper formed the background, while the front was left clear for exposure to the camera.   On a quarter-plate an exposure of 40 to 60 seconds was necessary..   A 9 by 7 inch Ross portrait lens

FIG. 11.   FIG. 12.

was employed at F. 11.   Color photographs of several of the columns have been obtained in this way.

MULTIPLE COLUMNS.

Regular formations of greater complexity were obtained when the bubble elements were reduced in size so that their diameters were less than that of the nozzle.   Thus, for example, two columns which coalesced into one are shown in two perpendicular views in Figs. 9 and 10 (see also Fig. 24).   The horizontal plane films between the successive elements of both columns were linked by a " staircase " of films, inclined right and left at 120° to the horizontal films; every bubble thus fitted into two bubbles of the

adjacent half column, the horizontal junction films being segments of circles, while the inclined films took the form of rectangles with their short sides slightly convex. The data for this formation were: Nozzle, 5 cm. diameter; air current, 130 c.c. per minute, with an interval of 15 seconds between successive drops. Each element of the column thus had a volume of $32\frac{1}{2}$ c.c. Three columns will also coalesce from top to bottom, twining round each other like the spiral strands of a rope. The plane films linking the bubble segments are then truncated sectors of circles.

A complex of four interpenetrating vertical columns is shown in Figs. 11 and 12. This may be considered as built up by a succession of horizontal pairs of bubbles, each pair being at right angles to the adjacent pairs above and below. The symmetrical pairs of horizontal plane films which link them are circular quadrants with their points in contact, and of course are alternately at right angles.

Fig. 13.

Between each member of the alternate horizontal pairs of bubbles there are vertical films which are diamond-shaped, and joined at their apices with their planes alternately at right angles along the axis of the cluster. The resulting appearance is very regular. One example of this formation was produced by a nozzle of 5 cm. diameter, with an air current of 400 c.c. a minute, and an interval of 4 to 5 seconds between the drops.

A still more complex but perfectly regular quadruple column has the simple string of diamond-shaped films replaced by alternate hexagons and squares of which only the hexagons are vertical. An isometric view of this part of the arrangement is shown in Fig. 13. The common edges of adjacent squares and hexagons are horizontal, and alternate squares are equally inclined in opposite directions to the axis of the complex column. The complete configuration is shown in Figs. 14 and 15 (two perpendicular views); the outlines are further displayed in Fig. 16.

Multiple columns of a higher order were obtained by lessening the time-interval between the drops. The excess liquid thus supplied tended to distort the cluster. This was avoided by employing a long nozzle within which the network of bubbles was formed and supported until the excess liquid drained away. The

cluster was then expanded clear of the nozzle, and remained stable and undistorted.   As many as seven or more interlaced vertical columns were obtained in this manner.   The centre bubbles of the cluster were of course completely enclosed, and hence had no curved surfaces, but formed instead a chain of film-enclosed cells. From the outermost facets of these there radiated a film structure of pyramidal frustums bounded externally by curved bubble films.

FIG. 14.   FIG. 15.

Two forms of these faceted " cells " are shown in Fig. 17; some have the regularity of a well-cut gem, and exhibit great brilliance in a concentrated light.   Some forms frequently occurring have (*a*) parallel regular hexagons top and bottom with pentagonal facets; others have (*b*) irregular heptagons at the top and bottom; the facets being then either pentagons alone or alternate hexagons and quadrilaterals, or even all three together.   An interesting example occurred when the quadruple column with alternate diamond-shaped planes distributed along the axis (Fig. 11) was disengaged from its nozzle and allowed to fall on the surface of

the soap solution 15 cm. below. The cluster had already drained to complete blackness, and was therefore so light that at first it rebounded several cms., finally floating on the surface for some time, delicately poised like a nautilus. However, it soon coalesced with the liquid surface, forming a half dodecahedron in the centre surrounded by a symmetrical ring of six half bubbles all resting on the liquid, and three whole bubbles superposed regularly above

Fig. 16.
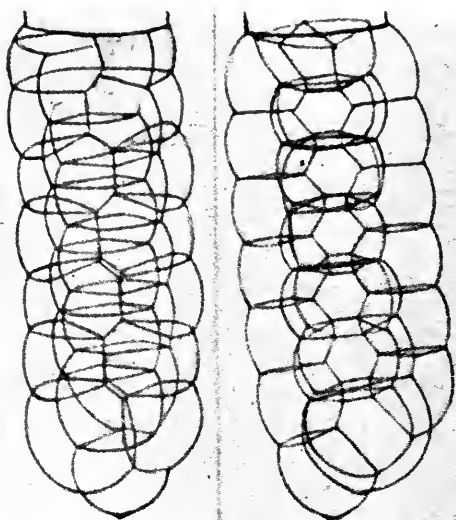
Fig. 17.
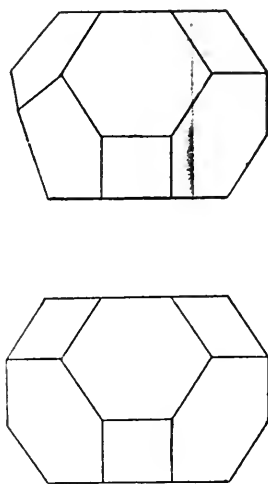
these, each of the nine external bubbles springing from one facet of the central " cell." The completed structure, of which this was the half, would thus have consisted of twelve pentagonal pyramidal frustums round a dodecahedron, the bases of the pyramids being the outer curved bubble surfaces. Such a complex was obtained separately, but it is difficult to show the configuration by means of a photograph.

SYMMETRICAL CLUSTERS OF BUBBLES.

Equal-sized bubbles are readily built up into well-defined groups that have many interesting properties. Their spherical contours, interlaced by a network of reflecting films, give them a graceful symmetry. Up to an aggregate of eight the growth is fairly simple. Each successive bubble springs instantaneously into its place with the appearance of being partly absorbed, though of course retaining its volume practically unchanged. Two bubbles

thus coalesce into two spherical segments joined by a circular plane film. When a third bubble is introduced between these two the spherical boundaries are further reduced, and are spaced out between three equally inclined plane films, which are segments of circles in contact round the axis of symmetry.

With four bubbles there are two possible arrangements; the more stable form has the fourth bubble resting symmetrically on the group of three, so that the four segments are equally spaced on the frame of a regular tetrahedron. Six plane films in the shape of circle sectors are thus produced by the four segments coalescing

FIG. 18.
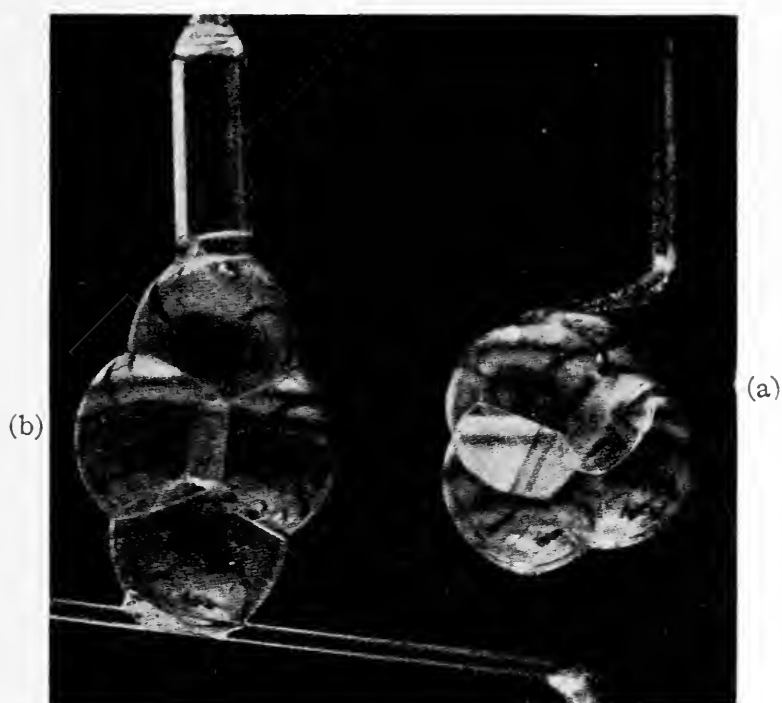
round the centroid of the tetrahedron (Fig. 18a). But if the fourth bubble be introduced between any two of the three-group instead of at the junction of all three, then the form shown in Fig. 18b is obtained, which has a central plane film shaped like a rectangle with its short sides slightly curved, and two pairs of equally inclined planes springing from its long sides. These five planes constitute a frame linking the four bubble segments together.

In Fig. 19 these frames outlined in wire are shown as they appear (a) for the group of three; and (b), (c) for the two forms

of the group of four; while Fig. 20 (outer set) gives the sections through the groups to show the inclination between the plane films, and the trace of the outer contours.

FIG. 19.

a   *b*   *c*
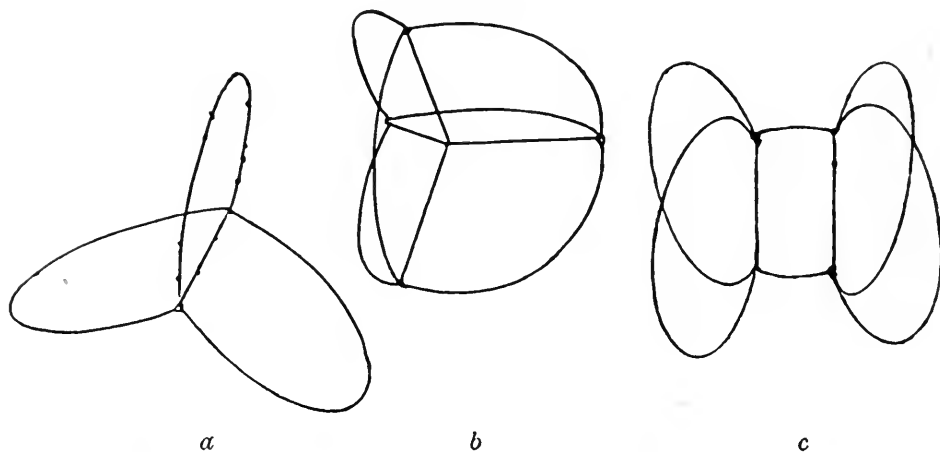
FIG. 20.
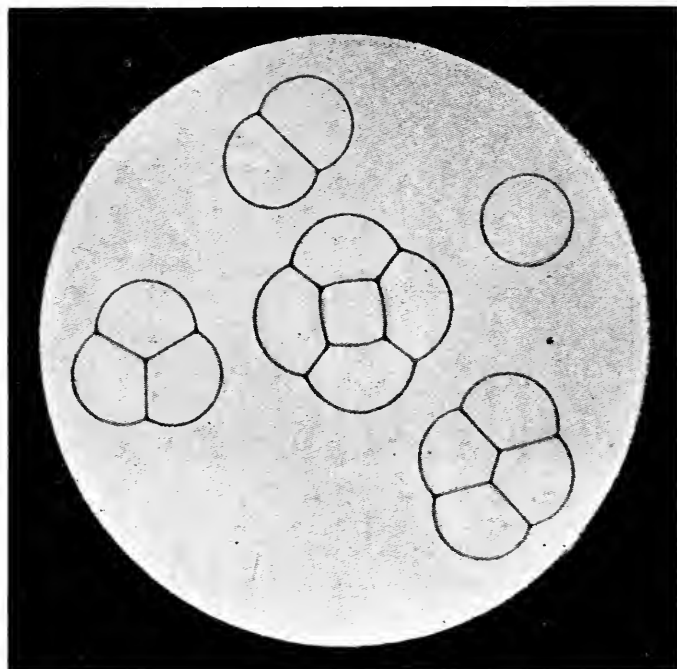
Only one arrangement of the five-group has been obtained. It is formed when two additional segments interpenetrate, one at each end of the axis of the three-group, the three upper plane films thus formed, meeting in one point of this axis, and the three lower plane films meeting in another point of the same axis.

The groups of six, seven and eight all have the same type of symmetry—namely, at the centre is a small plane polygon, from

FIG. 21a.
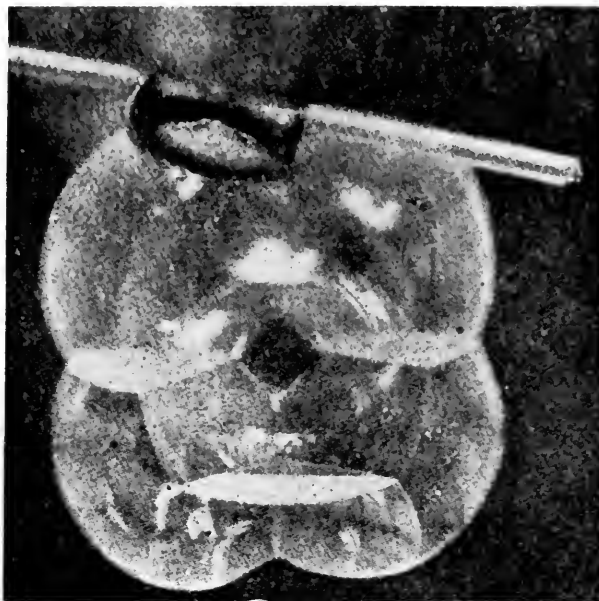
FIG. 21b.
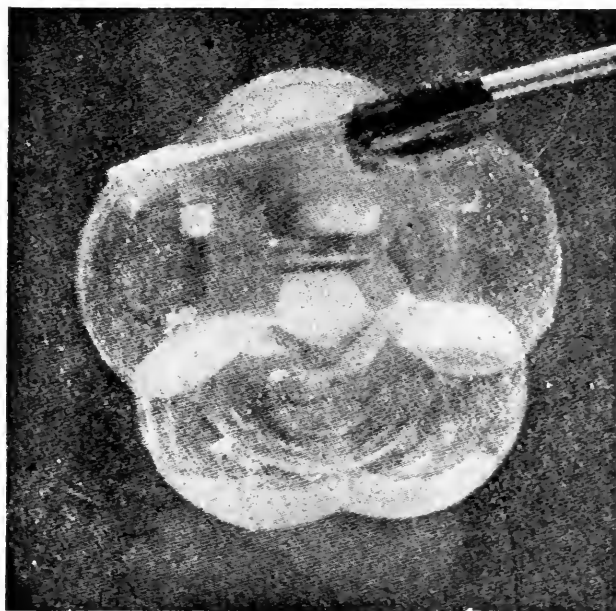
the sides of which there radiates a ring of bubble segments, equally spaced, with two others on an axis at right-angles to the central plane. The six-group therefore has a ring of four segments round

a square central plane, the two others being on opposite sides of
this central plane. The two interlocked bubble segments thus take
the form of two truncated square pyramids in contact with each
other on the central square plane, having their bases bulged out on
the spherical contour, and the four other segments built in round
the faces of the truncated pyramids (Fig. 21*a*). The section of
this is shown in the central group of Fig. 20. The groups of seven
and eight are similarly formed, except that the square central plane
is replaced by a pentagon and hexagon respectively. In all cases

FIG. 22.
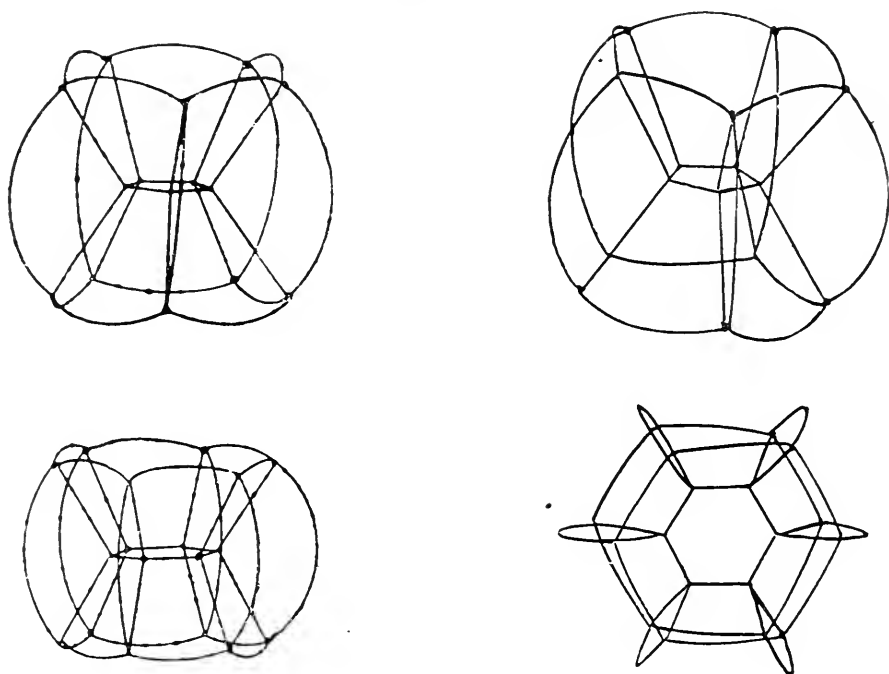
the polygon edges are slightly curved. Fig. 21*b* is a photograph
of the seven-group with pentagon centre. The wire frames for
this group and the eight-group with hexagon centre are shown in
Fig. 22, while sections through the two are given in Fig. 23.

These " sections " are in reality photographs of the half groups
when formed on a horizontal glass plate (4 inches square). A
fountain-pen filler was used to make the equal half bubbles, by
simply squeezing the indiarubber bulb quite flat, the nozzle having
already been dipped in soap solution, and the glass plate well-
moistened with solution. The single and double columns already
described may be shown in the same simple manner (Fig. 24). By
using the horizontal projection lantern these figures are plainly
shown on the screen.

FIG. 23.
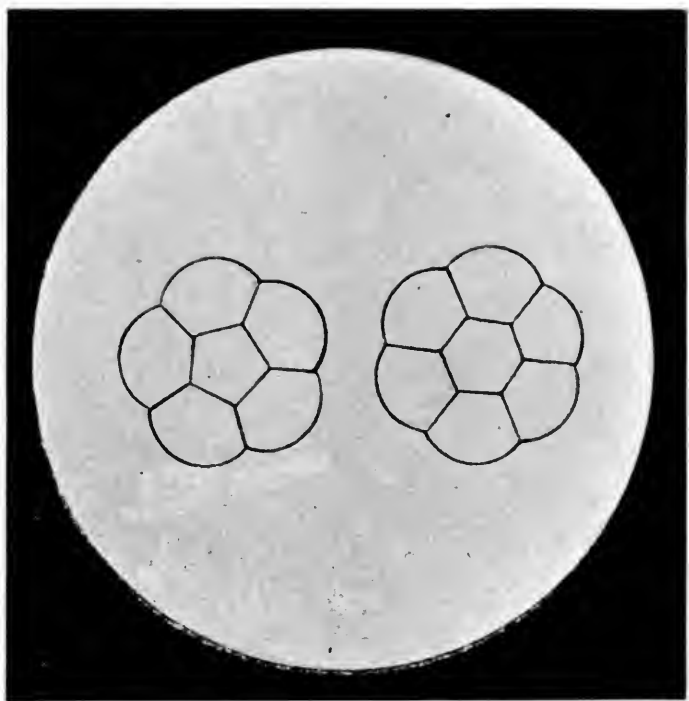
FIG. 24.
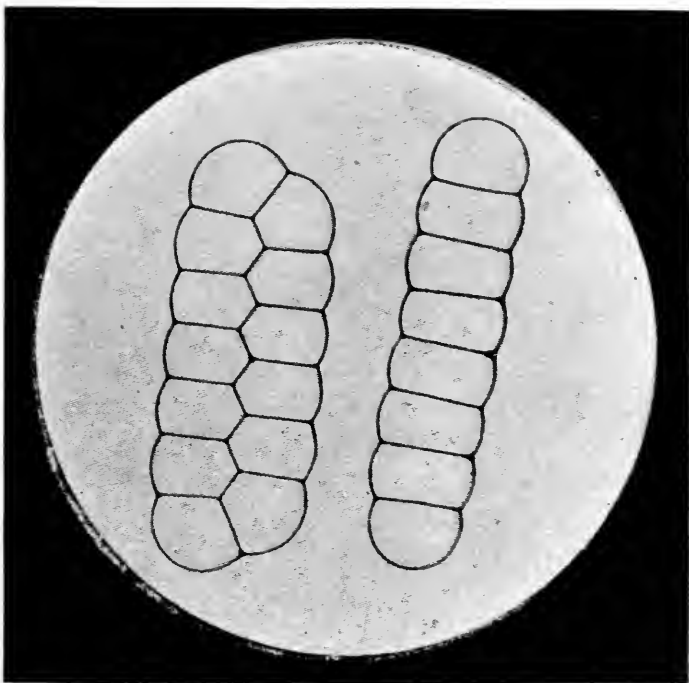
The forms taken by these clusters are governed by the conditions for equilibrium of the surface tensions at the intersections of the films. Not more than three films can meet in any one line, and if they are planes they will be equally inclined to one another at angles of 120°, while, if they are curved, then the law of equal inclinations holds between the tangent planes at all points of contact. Taking first the case of two bubbles which have coalesced into two segments united by a circular plane film, the tangent planes at any point of the line of contact of the curved surfaces will be inclined at 120° to each other and to the circular plane. It follows that the radius of the plane central film is $\dfrac{\sqrt{3}}{2}$ of the radius of the two equal spherical segments, the distance between their centres of curvature being equal to this radius, which is greater than the radius of the original separate bubbles in the ratio of $\sqrt[3]{4} : 1.5$ or $1.0 : 0.9452$. Therefore the internal excess pressure (which is inversely as the radius of curvature) is reduced 4.5 per cent. by the coalescence. Measurements made on two bubbles gave under 5 per cent.

Three spherical segments in contact are each approximately five-sevenths of a whole sphere. The internal pressures therefore are now reduced to the proportion of $\sqrt[3]{7} : \sqrt[3]{5}$ or $1 : 0.8933$. Now $0.8933 = (0.9452)^2$, so that the process appears to proceed by a geometrical progression, each linkage reducing the internal pressures in an equal proportion.

CONCENTRIC HALF BUBBLES.

An interesting application of the method of film formation by regulated drops was made in order to obtain a group of concentric hemispherical bubbles. It was desired to obtain them with a uniform difference of radii of 1 cm. between successive film surfaces. They were blown on the under side of the top glass plate of a smaller cubical vessel (30 cm. length of edge). A special form of nozzle was made with its rim flush with the surface on which the bubbles were to be blown. The part containing the narrow neck was of ebonite, and had a shoulder carefully fitted to the aperture in the glass plate. The dropping funnel and glass blowing tube were fitted tightly into the neck of the ebonite nozzle. Fig. 25 shows the arrangement with a group of ten half bubbles, the horizontal

lines indicating the levels reached by black zones on the fourth day.

In order to determine the time at which each drop had to fall the volumes of the successive bubbles were calculated and their differences tabulated. Having fixed upon a suitable rate of blowing, the intervals between the drops that corresponded to the successive differences in volume were at once obtained. The rate of blowing was 216 c.c. per minute, so that the whole group took about 21 minutes to make, the intervals between the drops

FIG. 25.
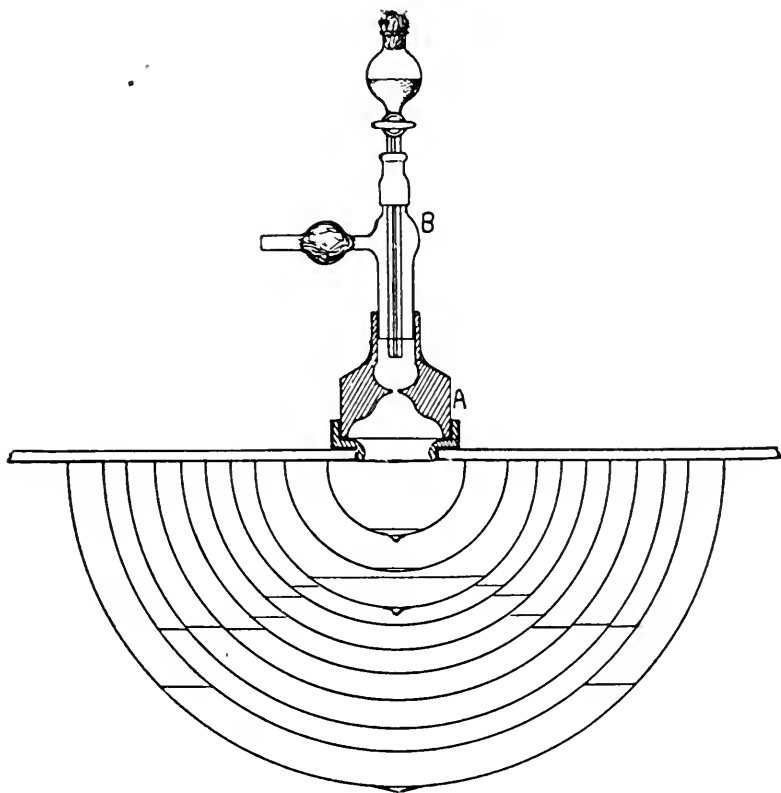
decreasing from about 4½ minutes at first to about half a minute at the end. The surfaces of the glass plate and nozzle were first moistened with soap solution.

By the eighth day the black zones occupied 90 to 95 per cent. of the surfaces. Some experiments were made subsequently on the manner of diffusion of hydrogen through the group.

FILM CONTOURS SHOWN BY SHADOW.

When the shadows of these film complexes were thrown on a transparent screen every detail of their structure was clearly shown. For lecture purposes an arc lamp was used to produce

these shadowgraphs, but in the laboratory a beam of parallel rays throwing the shadows on a sheet of tissue paper fixed on the side of the cubical glass chamber (containing the film-cluster), opposite to the source of light, gave means of making accurate measurements both of lines and inclinations of planes, as well as careful tracings for further study.   Fig. 16 shows the shadow picture given by the quadruple column shown in Figs. 14 and 15.

WIRE MODELS OF BUBBLE CLUSTERS AND PLATEAU FRAMES.

The wire frames already mentioned can be used to build up the corresponding clusters.   When they are dipped in soap solution linked films are formed on every plane outlined by the wires, because these are in the same stable relation that exists in the associated bubble group.   It is then possible to insert bubble segments into the spaces between the planes and thus build up the actual cluster on a wire frame.

These form an interesting comparison with the well-known Plateau film groups, which were formed on wire frames made in the shape of geometrical solids—cube, tetrahedron, triangular prisms, etc.   When such frames were dipped in soap solution linked film planes were obtained in beautiful regular formation, though not necessarily lying in the planes of the solid figure represented in skeleton by the wire, because these planes are not the stable planes of liquid films in contact.   The film figures finally obtained were enclosed within the space of the skeleton figure.   Thus the films initially obtained on the six faces of the skeleton cube are pulled inward until they meet at an angle of 120° instead of the original right-angle.   As a result a small vertical or horizontal square is formed at the centre with a pair of equally inclined truncated triangles radiating from each of its edges to the parallel edges of the cube; this gives eight equal truncated triangles linked by the central square.   If a small bubble is included, this is drawn into a cuboid at the centre with the remaining planes as before.   So with a tetrahedron, six planes are seen to be drawn inward one from each edge, to the four lines joining the apices to the centroid. This point is therefore common to the six planes which thus divide the space inside the tetrahedron into four equal and similar parts, like the conventional model of the four affinities of a carbon atom.   A double tetrahedron has this appearance repeated at each end.   Using an octahedron frame, we obtain six kite-shaped

figures, in three perpendicular pairs, linking the three pairs of opposite vertices, and having their obtuse ends fitting alternately at the centre, while the acute ends stretch out to the apices. These six kites are connected to the twelve edges of the frame by twelve triangular planes, making eighteen films altogether.

A hexagonal prism is an interesting case illustrating the impossibility of getting more than three films to meet at one point. A

Fig. 26.

(a)

(b)

(c)

(d)
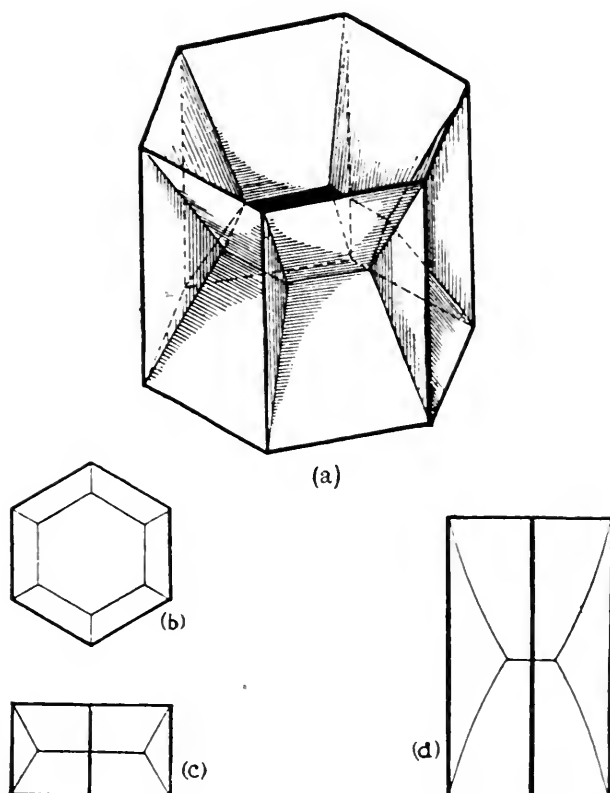
wire prism of indifferent dimensions—say, with its hexagonal edge of the same order of length as its height—will give six triangular vertical films directed from each vertical edge toward the centre, where their apices are linked by a horizontal hexagon (Fig. 26). There are in addition six pairs of truncated triangular films linking top and bottom opposite hexagonal prism edges to the parallel central film hexagon, Fig. 26 (a, b, c). If the prism height is increased and this configuration preserved, then the central hexagon will decrease in dimensions and should vanish when the height of the prism is three times its hexagonal side, all the eighteen films then meeting at the centre. What happens during

the process is shown in Fig. 26 (d) : The central hexagon is pre-
served, the vertical planes are no longer triangles but have sides
concaved towards the apex, while the twelve remaining surfaces
springing from the top and bottom edges are curved and look like
a sort of hexagonal hour-glass—seen in profile (d). The con-
dition governing all these arrangements is the equal inclinations of
the tangent planes at the lines of intersection.

One interesting variation of this study was made by employing

Fig. 27.
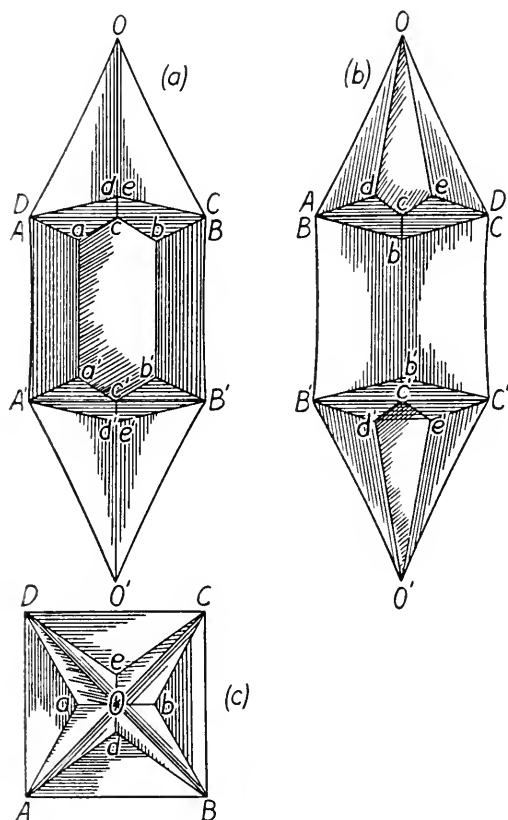
a frame composed of two thin platinum wire squares, linked by
cellulose fibres vertically between the corners to form a cube, and
supported by a pyramidal frame formed by four equal fibres from
the upper cube corners joined together at the supporting apex. A
similar pyramidal frame inverted was also formed below, the four
fibres in this case being attached to a small lead weight. The
resulting formation when the framework was dipped in soap solu-
tion is represented geometrically in the following three views, two
elevations (a) and (b) and a plan (c) (Fig. 27).

This is really a combination of the cube and the octahedron patterns (already described) obtained by equally dividing the octahedron horizontally, and adding the separated portions to the top and bottom of the cube. The central square plane of the simple cube is thereby pulled out to an irregular hexagon *a c b b' c' a'* by the kite-shaped planes O *d c e,* O' *d' c' e'*, of the divided octahedron, with a consequent rearrangement of all the films at equal inclinations.

The truncated triangular films joining the vertical edges of the cube to the central (hexagon) plane then become very short. In Fig. 27 (*a*) they are shown by A *a a'* A' and B *b b'* B', while in Fig. 27 (*b*) the other two are shown by C *b b'* C', and by D *b b'* D' behind. All four are shown in profile in Fig. 27 (*c*) by the lines A *a*, D *a*, B *b* and C *b*. The kite-shaped planes from the apices O and O' of the divided octahedron are Fig. 27 (*b*) O *d c e* and O' *d' c' e'*, which in Fig. 27 (*a*) are only seen in profile—*i.e.*, perpendicular to the central irregular hexagon *a c b b' c' a'*.

The edges of the two pyramids (half-octahedrons) being O A, O B, O C, O D, O' A', O' B', O' C', O' D', then the triangular films drawn in from four upper edges are in Fig. 27 (*a*) and (*b*) O A *d*, O B *d*, O C *e* and O D *e* behind O C *e*. Similarly for the four lower edges. These triangular films also seen foreshortened in Fig. 27 (*c*) are indicated by the same letters.

From the upper horizontal edges of the cube there also spring four triangular films in two pairs, matched on opposite sides; those from the side edges A D, B C, Fig. 27 (*c*), go down to the central hexagon at *a* and *b*, Fig. 27 (*a*), while those from the front and back edges A B, D C, join up to the kite-shaped plane at *d* and *e*, Fig. 27 (*b*). The four films are thus shown in Fig. 27 (*c*) by A D *a*, B C *b*, and A B *d*, D C *e*. The same is repeated from the four lower edges of the cube, A' B', B' C', etc. There then remain two pairs of quadrilateral films linking the kites and the hexagon to the triangular films from the edges. These last are represented by A *d c a*, B *d c b*, in Fig. 27 (*a*), and C *e c b* in Fig. 27 (*c*); the other would be D *e c d* behind C *e c b*. The same is repeated on the lower edges.

The whole complex thus numbers 31 films: 12 from the cube edges, 8 from the pyramid edges, and 8 quadrilateral films, together with the kite-shaped pair and the irregular hexagon forming the backbone of the figure.

EXTENSIBILITY OF COLUMNS.

When groups of bubbles are first formed the films of which they are constituted are rather thick, because as a rule the segments are not expanded to any great size. Owing, however, to the free drainage down the intersecting channels, the excess liquid rapidly

Fig. 28.

(a)

(b)

cm's

H diffused out: column on point of pulling apart at ←

freshly blown

drained to blackness

7% H in bubbles
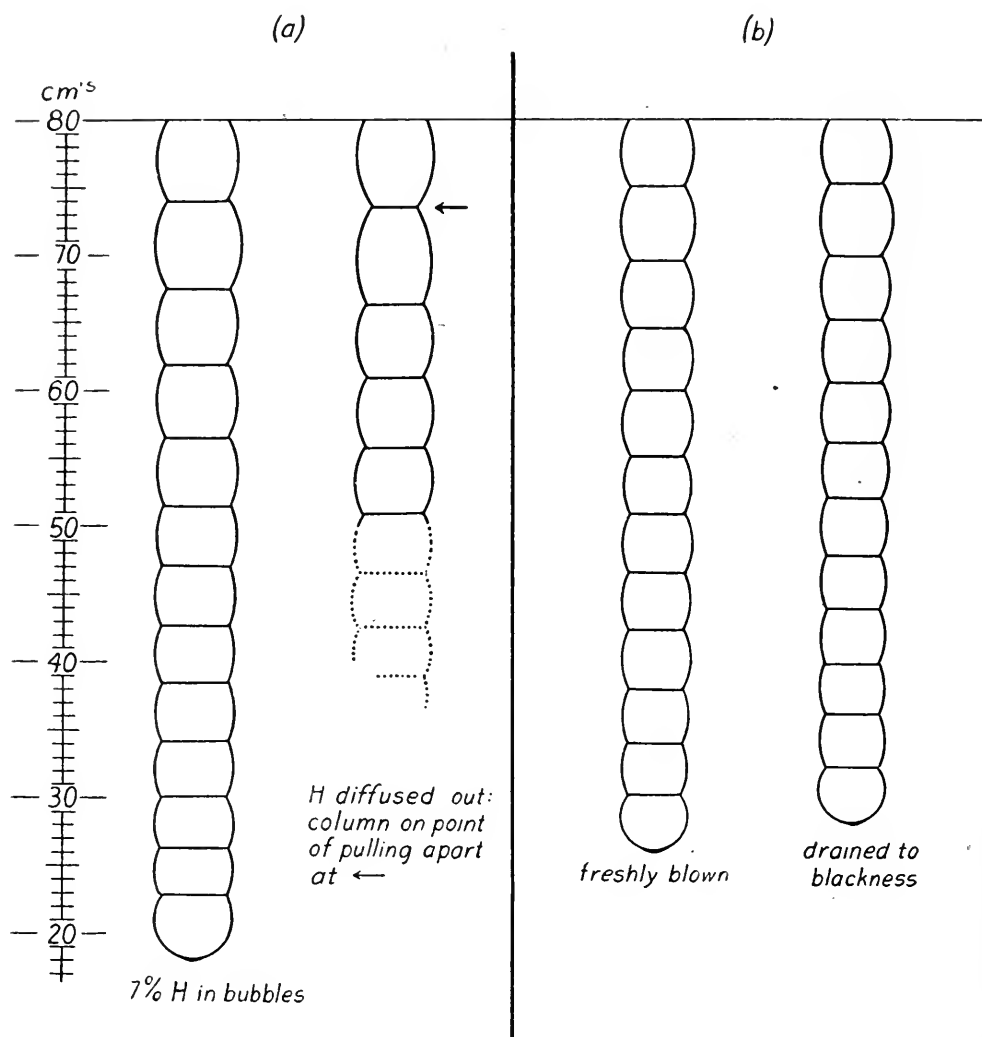
accumulates in the lower segments, and the weight thus localized distorts or breaks the group.

Some measures were therefore made of the elongations produced by added weights in various forms. In a single column it can be seen that the upper segments are longer than those lower down; with additional loading the extension increases until parting takes place. This is illustrated in Fig. 28 (which is drawn to scale). A column of 13 bubbles is shown at (a) when freshly blown with air

containing 7 per cent. of hydrogen. After the hydrogen had diffused out for five minutes, the loss of buoyancy produced the sag shown in the second drawing (*a*), taken when rupture was imminent between the first and second segments; the measurements could not, therefore, be completed. The ratio of length to breadth of the longest segment (on the point of instability) is 1.17 to 1. Comparative measures are also shown in the drawings (*b*) of the considerable contraction that takes place in an air-blown column between its early condition when uniformly colored, with all superfluous liquid removed, and its final condition of complete blackness, and therefore minimum mass. The successive heights of the segments in a column half an hour after blowing (uniformly colored, no excess liquid) were, counting from the top, 5.1 to 5.2 cm. for the first four; then in succession, 5.0, 4.8, 4.3, 4.2, 4.0, 3.8, 3.2—at which point contact was made with a larger segment on a fixed support.

The long glass cylinder in Fig. 6 was chiefly used for these measurements. The sliding support rod was adapted for manipulating a separate light glass ring, on which small weighed pieces of steel wire could be hung. A graduated pull could be exerted by a small solenoid below. Tiny horizontal magnets were attached to the columns, and by their tendency to set in the meredian were able to retard irregular oscillations. For this purpose they were fixed to light cotton rings by being soaked in nitro-cotton solution and dried.

A column of six segments each of 150 c.c. was elongated by one-third of its length with a weight of 0.136 gram; the original length, free of superfluous liquid, being 31.0 cm., and the maximum elongation, 11 cm.; the smallest additional weight then broke the column. The same weight, hung on a column of five bubbles 23 cm. long, caused an elongation of 8.3 cm., or 35 per cent. On the removal of a drop of liquid weighing 6 centigrams a contraction of 2.3 cm. followed.

A column of three segments gave the following result: With a weight of .075 gm. its initial length was 14.7 cm., and the elongation produced was 1.35 cm.

The following values were obtained from the gradual increase of load when a loss of buoyancy occurred by diffusion of hydrogen from a column of eight equal segments of 150 c.c. blown with 7 per cent. hydrogen. The initial length of 35 cm. was increased to

39.5 cm. when a weight of 7.5 centigrams was hung on. When the hydrogen had diffused out the total length became 40.3 cm., or an extension of 0.8 cm. from an additional weight of 8.4 milligrams. These results are recorded in the following table (I).

TABLE I.

n	l	w	e	wl	x	wl/x	E
	cm.	gm.	cm.				
6	31	.136	11	4.22	.355	11.9	.383
5	23	.136	8.3	3.13	.361	8.7	.377
5	23	.136–.006	8.3–2.3	2.99	.261	11.5	.498
3	14.7	.075	1.35	1.10	.092	12.0	.817
8	35	.075	4.5	2.63	.129	20.4	.583
8	35	.0834	5.3	2.92	.152	19.3	.552

Where n is the number of segments in the column; l is its length in cms.; w is the attached weight in gms.; e is the elongation in cms.; x is the elongation per unit length of column; and E is the corresponding value of Young's modulus.

It will be noticed, on comparing the fourth set of these observations with the first set, that (roughly) halving the weight and length reduced the elongation per unit length to one-fourth, as might be expected. For, $x = \frac{e}{l}$ and $W = E\frac{e}{l}$, hence for the first case $W\,l = E\,e$; for the second case, $W'\,l' = E'\,e'$, or $W\,l = 4\,E'\,e'$. $\therefore\ 4\,E'\,e' = E\,e$. Now in the Table I, $E' = .817$, $E = .383$, or approximately $E' = 2\,E$, hence the last expression becomes $8\,e' = e$, or in terms of x, $8\,x'\,\tfrac{1}{2}\,l = x\,l$, whence $4\,x' = x$.

GAS TRANSFERENCE THROUGH FILM COMPLEXES.

Columns and clusters of bubbles generally reach the " black " stage with great rapidity by the action of the channels (Gibbs rings) of liquid where segments join together. The black development of an ordinary hanging bubble is different from that of a similar bubble resting on a ring, because in the latter case the action of the Gibbs ring is to assist gravity in withdrawing liquid from the film and thus to accelerate the thinning process, while in the former case the action of the Gibbs ring is against gravity, and thus retards the withdrawal of liquid from the film. The two curves in Fig. 29 show this difference very clearly: The black boundary on the poised bubble descending at an ever-

increasing rate, as it approaches the Gibbs canal present on the support ring; while in the hanging bubble the rate of fall continually decreases. (This is more noticeable when liquid is allowed to

FIG. 29.

Black Development in a
Hanging Bubble

(a)

Black Development in
Bubble Poised on Ring

(b)
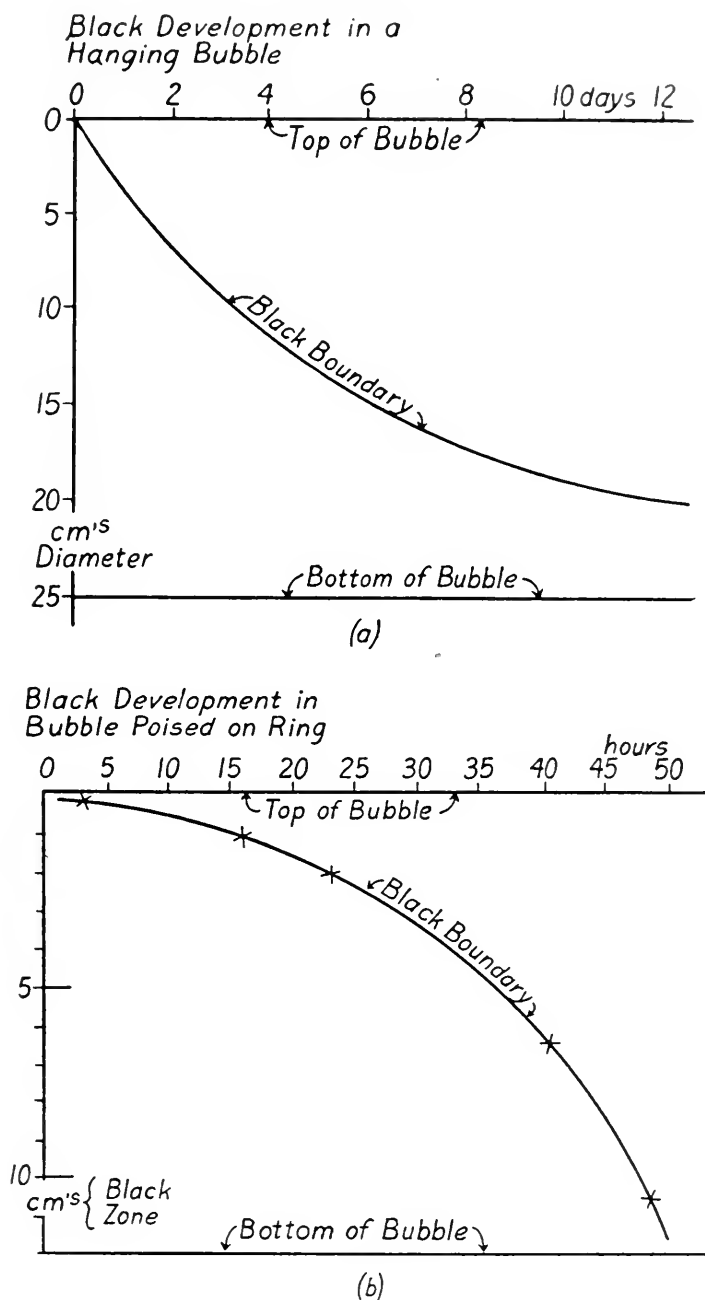
accumulate below while the thin black area extends downward. In the absence of suitable drainage, the colored zone then becomes continually thicker.) When, however, a bubble was provided

with two Gibbs rings, one above and one below, the rate of fall of the black boundary was almost linear for the greater part of the time.

This was arranged by attaching a small bubble under a large one, supported as usual from a nozzle above. The small bubble was kept steady by a smaller glass ring underneath. The nozzle was 8.3 cm. in diameter, and the size of the small attached bubble was adjusted so that the diameter of the Gibbs ring of contact

Fig. 30.
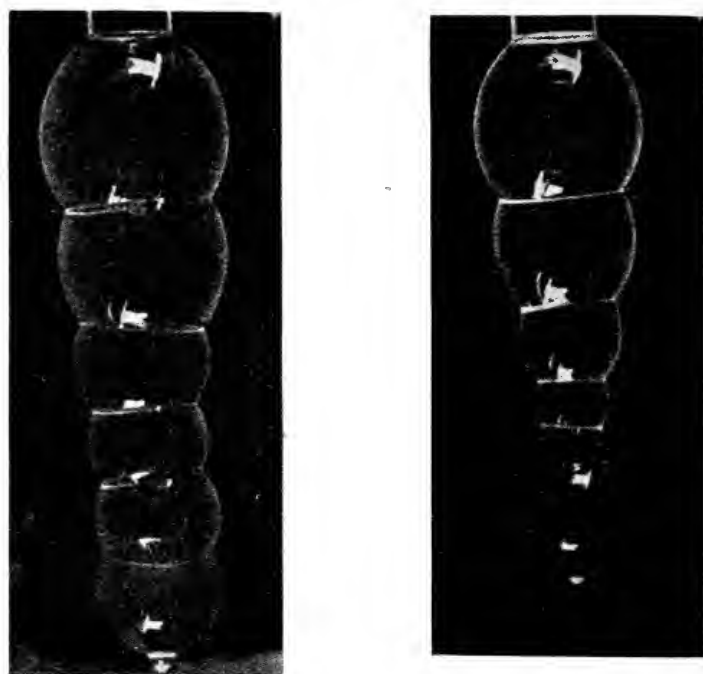
between the two bubbles was about the same. The greater bubble was 40 cm. high between the equal Gibbs rings top and bottom, *viz.*, where contact was made with the nozzle above, and the small bubble film below. The graph of " black fall " plotted with time was very nearly straight for 2½ days, by which time the black area had extended over three-fourths of the surface. After this it spread more slowly, and took another day and a half to reach the lowest point. The form was therefore intermediate between curves (*a*) and (*b*) of Fig. 29.

Now, in the more complex clusters there are many channels all connected at various inclinations, therefore not only is any excess liquid quickly discharged, but the films themselves are quickly drained to the " black " state.

This is the most favorable condition for the study of gas transference, as the film is then at its minimum thickness. The resulting contraction has been measured in the case of straight columns and other complexes by photographs taken periodically. These afford direct evidence of greater rate of transference in the smaller bubbles; for when records are taken of a column of unequal segments it is easily seen that the initial inequalities are accentuated as time goes on. Figs. 30 and 31 are reproductions from photographs of

FIG. 31.
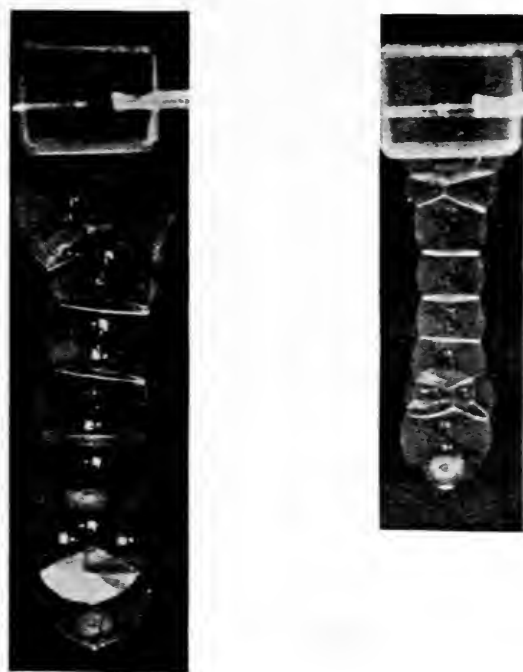
two small columns at intervals of nine and seven days respectively; the volumes of the segments varied from 30 to 100 cm.

Large black volumes were more difficult to deal with on account of irregular oscillations; their relatively small mass when black was insufficient to stabilize them against any local convection. For example, in the 200 litre globe already described a column was blown consisting of six segments, the upper five of which had each a capacity of 1½ litres, while that of the lowest was 3 litres. In one day it became wholly black with the exception of a thick colored area that extended up over 30 per cent. of the lowest bubble, the weight of which was sufficient to keep the whole hanging vertically, although some of the junction planes were slightly inclined. By the sixth day the color had diminished to a zone 5 cm. wide.

This reduced load could not keep the column straight, and some of the oscillations that occurred displaced the drop on the lowest bubble as much as 15 cm. from the vertical, while a vertical contraction of 15 mm. had accrued, followed in the next two days by a further contraction of 6½ mm. The colored zone was now a disc of 2 cm. diameter, and the column had become so curved that an unusually large oscillation caused the lowest bubble to touch the globe, with the result that only the two uppermost segments remained, the junction plane between them being inclined at 30° to the horizontal.

A light glass ring was therefore arranged below to keep the column stationary. It was sealed to a 3 mm. glass rod bent round in a bow, roughly to follow the contour of the globe, and then secured to a vertical glass rod that could slide air-tight in the rubber stopper at the neck. The contraction of the column due to the gas transference, however, went beyond the limits through which the glass rod could be raised. The segments therefore became thinner and more strained, until on the eighty-ninth day separation took place between the third and fourth. The glass ring thereupon relaxed a distance of 8 mm., the amount by which the glass bow had been strained by the pull of the black column.

In some cases the various segments were measured daily by a cathetometer and horizontal sliding telescope. If D is the diameter of a bubble segment at the equator, and d the diameter of the plane circular ends, while h is the height, then the volume is given by

$$V = 1.0472h \; (0.4 \; D^2 + 0.2 \; Dd + 0.15d^2).$$

When the segment is unstrained, $d = D - 0.268h$, so that

$$V = 1.0472h \; (0.75 \; D^2 - 0.130 \; Dh + 0.01h^2) \; ;$$

only D and h need therefore be measured.

These relations were found to agree very well with the dimensions of segments of known volume.

The area of the curved surface through which the gas transference takes place (there being practically no loss through the plane ends) is given for a bubble whose centre of curvature is not in the axis of revolution by

$$S = \frac{\pi^2}{3} Dh - \left(2\frac{\pi^2}{3} - 2\pi \right) h^2 = 3.289 \; Dh - 0.295 \; h^2.$$

It must be noted that an uncontracted bubble segment has been assumed. This, however, was no longer the case when it became necessary to fix the column at both ends (to a nozzle above and a glass ring below). As the contraction proceeded therefore the total length did not alter, so that h remained practically the same
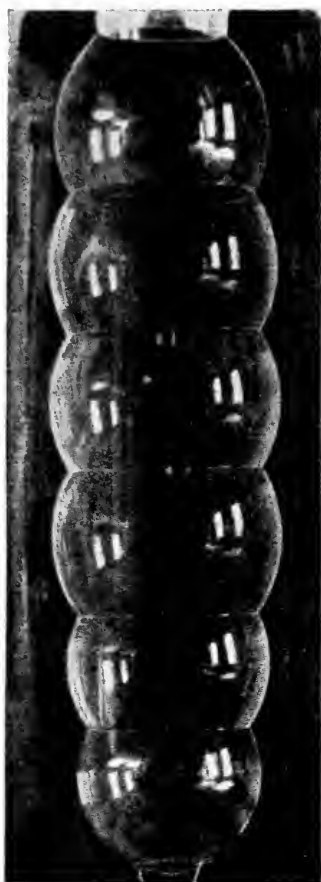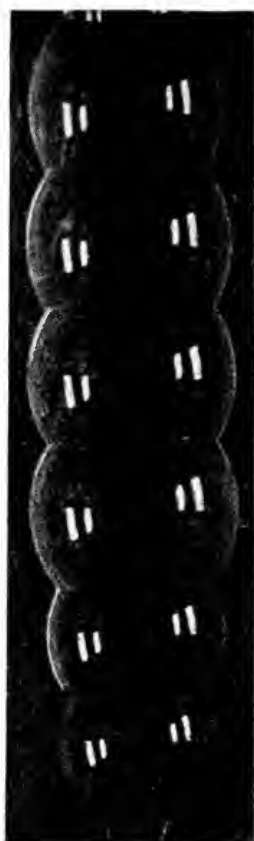
throughout; but as the segments shrank D and d continually diminished. Three illustrations of this are shown in Figs. 32–34. They are taken from a column of six bubbles in the 200 litre globe already described. The four top bubbles were of equal volume, while the two lowest were half the volume of the others. The third segment being between two similar ones remained symmetrical to the end, and thus gave more reliable results. The contraction finally resulted in the column pulling apart between the fifth and sixth bubbles on the sixty-fourth day. The upper five were thus left free, but the oscillations were so persistent that only

a blurred photograph was possible; this was, however, sufficient to give some measures of the free segments for comparison with those obtained when strained. Fig. 32 was taken at the start, Fig. 33 on the sixteenth day, and Fig. 34 on the sixty-fourth day before partition took place.

The volumes and surfaces for the third segment selected for calculation were as follows (Table II):

Black Six-Bubble Chain.

TABLE II.

DIMENSIONS OF SEGMENT (3).

Time................	1 (Fig. 32)	16 (Fig. 33)	64 (Fig. 34)	Days
Volume	1133	1029	543	c.c.'s
Curved Surface........	360	350.5	258	(cm.)^2

TABLE III.

AIR TRANSFER THROUGH SEGMENT (3).

Volume	1000	750	650	600	c.c.'s
Curved Surface............	346	305	288	279	(cm.)^2
Rate of Transfer.. { c.c's	7.6	11.3	14	.16	through whole surface
{ per day	0.022	0.037	0.049	0.059	per (cm.)^2
Volume Contraction	0.76	1.51	2.15	2.67	per cent. per day

When the values were plotted with time, contraction curves were obtained for both volume and surface. By taking tangents to the volume and time curve at successive intervals of time, the corresponding rates of gas transference $\dfrac{dV}{s}$ were deduced.

The third segment thus gave the values shown in Table III for air transference through the black film composed of $3\frac{1}{3}$ per cent. ammonium oleate and 33 per cent. glycerin.

Three sets of these columns in the 200 litre globe were tried. The first was the largest in volume and took 101 days to pull apart. Figs. 35 and 36 show the appearances at start and finish, the total length meantime had been reduced from 53.3 to 50.9 cm.; after this the free bubbles remained on the nozzle a further 53 days. They were then replaced by the second set already described, which took 64 days before it divided. The third set which followed was more uniform, consisting of one segment, top and bottom, each of

whose volumes was half a litre, while the four in the middle contained one litre each. This set parted in 40 days.

Very good black columns were also obtained in the long glass cylinder (Fig. 6). With this it was possible to prevent undue straining of the segments by carefully raising the support ring

FIG. 35.   FIG. 36.

when necessary. The cylinder was long enough to get in ten segments each of over 250 c.c. A thin thread of stranded cellulose (artificial silk) was sometimes fixed both at the nozzle and support ring to lie along the outer contour of the column from top to bottom. This not only stabilized the column while being blown, but accelerated the drainage and black development, because any excess liquid in the Gibbs ring channels of the junction planes was quickly drawn into the capillary canals of the silk. The result was that the black stage was complete in one day, and there was entire

absence of any deformation from superfluous liquid remaining in the junction rings. One set took 47 days before the shrinkage caused the segments to part, the support ring not having been raised. The ratio of length to breadth of the equal segments two days before this occurred was 1.5 : 1, as compared to 1.17 : 1 in a similar colored column of like dimensions, but without any cellulose thread, and dragged apart by loading (see Fig. 28).

The segment volumes of another set diminished during the first fortnight from 270 c.c. to 225 c.c., and the curved surfaces from 145 to 120 square centimetres. The calculated rates of air transference obtained from the contraction curves are given in Table IV; the solution used contained 5 per cent. ammonium oleate and 50 per cent. glycerin.

<div align="center">Table IV.</div>

Volume	265	250	235	c.c.'s
Curved Surface	143	139.5	136	(cm.)²
Rate of Transfer . . . . . . $\left\{ \begin{array}{l} \text{c.c.'s per} \\ \text{day.} \end{array} \right.$	1.83	3.62	5.24	through whole surface
	0.013	0.026	0.039	per (cm.)²
Volume Contraction	0.69	1.45	2.23	per cent. per day

Much higher values were given by a black column of five equal segments, initially 161 c.c., very completely drained by two cellulose strands on opposite sides of the bubble contours. No glass ring support was employed, so the column contracted freely without the segments being strained out of their normal curvature. In four days the volume diminished 30 per cent. The mean rate of air transference being nearly 11 c.c. per day when each segment had a volume of approximately 125 c.c. The corresponding value of the curved surface was about 80 (cm.)², so that the loss through unit area was 0.14 c.c. per day. The solution used for this contained 1 per cent. ammonium oleate to 10 per cent. of glycerin.

<div align="center">GAS DIFFUSION THROUGH BLACK FILMS.</div>

The rate at which gases diffuse through liquid films was found to be very much greater than the slow escape caused by the small excess-pressure by which bubbles are distended. The latter only

b:comes appreciable some days after the black stage is reached; but if a thick colored air bubble has a small percentage of hydrogen blown into it, a contraction takes place in a few minutes; or, conversely, an expansion is quickly produced by circulating some hydrogen in the closed vessel in which the bubble is hanging. In the same way when a plane film was formed across a cylindrical vessel containing only air and some soap solution, and hydrogen was then circulated in the space between the film and the neck, a steady movement of the film towards the neck at once began; the hydrogen passed through to the enclosed space beyond the film more quickly than the contained air diffused out. The reverse process was easily carried out by first filling the bottle with pure hydrogen, and expanding the film as before. A current of clean air was then circulated on the same side of the film as before; the resulting movement of the film was now away from the neck, because the volume enclosed beyond the film lost hydrogen more quickly than air could diffuse in. When oxygen was used instead of air the motion was more rapid.

When these experiments were made after the black stage was reached, the diffusion was sufficiently rapid to cause a large distortion of the plane film, due to partial adhesion round the periphery of the film, although the glass walls had previously been well moistened. For the laboratory measures of the relative diffusion rates of various gases, an 8 litre bottle, 19 cm. in diameter, was calibrated, and the movements of the film (which would thus have an area of some 300 cm.²) were noted for successive small time intervals. The stopper was fitted with inlet and outlet tubes, of which the former was long enough to reach the bottom, and could also slide easily in an air-tight fitting. The film was thereby started by pushing the inlet tube down into a small quantity of soap solution in the bottle, and then withdrawing it gradually as the gas current expanded it to the desired position. The tube was then pulled just through the film, the current nearly shut off, and the whole left to settle until the black zone had developed sufficiently in the firm. The gas to be circulated was then connected and turned on, and the movements of the film noted. The end of the outlet tube was kept within a cm. of the film surface to maintain a thorough circulation.

With hydrogen in the vessel, and when the film was half black and half silvery (next in thickness to black), and air was circu-

lating at 130 c.c. per minute, the volume enclosed by the film decreased at a fairly uniform rate of 1 litre in 20 minutes. After this movement became slower as the percentage of hydrogen diminished in the space beyond the film. Finally, 5.70 litres of hydrogen originally present were found to be replaced by 1.40 litre of air. In another experiment, with the firm almost completely black, 6.23 litres of hydrogen diffused out and were replaced by 1.35 litre of air.

Fig. 37.

The maximum rate of diffusion could not be realized in this wide vessel because of the film distortion that was produced when the rate of circulation was increased. To overcome this a vessel only 8.5 cm. in diameter was used. (Fig. 37), in which the ordinary stopcock was replaced by a two-way cock A, while an inlet and outlet fitting was fixed in the rubber stopper. The outlet tube as before could slide easily in its air-tight neck. The vessel was filled with hydrogen coming in through A and leaving at B. The film was obtained (after first moistening the walls of the vessel) by tilting a drop of the soap solution into the neck at A. The gas entering there at once formed a film and pushed it along to the desired position. A was then closed and the film left to become black. Meanwhile a small current of hydrogen was continued through B and C to prevent any subsequent disturbance of the film, such as by an alteration of temperature.

Before starting the air or oxygen current through B and C the film was lubricated by a slow complete revolution of the vessel, whereby the small amount of liquid inside flowed all round the walls. This caused some diminution of the black area, which was measured and allowed for. During the subsequent diffusion the sliding tube was adjusted so that its open end was kept within a centimetre of the moving film. Small measured samples of the mixed gases behind the films were withdrawn at intervals for analysis through the two-way cock A.

The maximum rate of diffusion of hydrogen above that of air was found to be 42 c.c. per hour per cm². When oxygen was used

instead of air the value obtained was 50 c.c. of hydrogen per hour per cm.² greater than the oxygen going the other way; and 1145 c.c. of hydrogen passed out, while 632 c.c. of oxygen went in. When the reverse process was tried 1173 c.c. of hydrogen went in through the black film, while 635 c.c. of oxygen diffused out. The

FIG. 38.

Hydrogen Oxygen Diffusion through Black Film
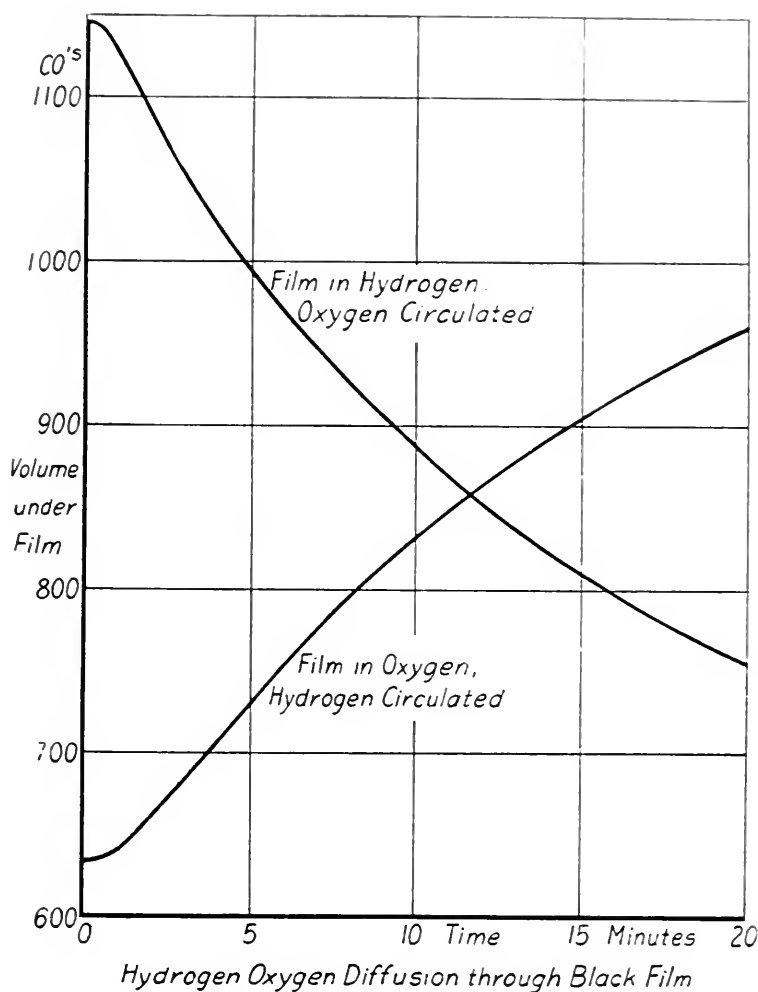
two operations involved the passage of the film 7 cm. along the cylinder in the first case, and the same back again for the reversal. Fig. 38 gives the graphs of the movement of the film, and shows the variation of the enclosed volume, with the time. The rate of relative diffusion at any time is given by the slope of the tangent to volume-time curves. This was found to decrease as the proportion of oxygen under the film increased.

The contraction of bubbles in air when blown up with from

10 per cent. to 30 per cent. of hydrogen was measured in order to deduce the diffusion rates through colored films. A much lower value was obtained; thus a bubble colored steely blue to pale amber and containing 16 per cent. of hydrogen showed a rate of contraction of approximately $^2/_3$ c.c. per hour per cm². Measures were also made with half bubbles blown on the roof of a glass chamber in which a proportion of hydrogen was circulated; and also by comparing the contractions of similar bubbles when hanging from a nozzle and resting on a ring. This last was done to correct for the distortion of figure produced by the buoyancy of the contained hydrogen.

HYDROGEN BUBBLES BLOWN UNDER SEVERAL ATMOSPHERES.

Bubbles that have thinned to blackness contract at an ever-increasing rate by the continual transference of the enclosed gas through the envelope. It was mentioned in last year's Discourse that the contraction is greatly retarded when the bubbles are formed in an enclosure in which the pressure has been raised, the excess-pressure distending the bubble becoming then of relatively smaller proportion to the total pressure. Further experiments have shown that a black bubble in hydrogen under 6.3 atmospheres pressure took 100 days for its diameter to contract from 7.7 to 4.0 cm., whereas only 7 to 10 days is needed for the same contraction to take place in a similar bubble at atmospheric pressure. When air was used instead of hydrogen the difference was equally marked; thus an 8 cm. bubble in a vessel charged to 7 atmospheres took 4 months to diminish 1 cm. in diameter, the same contraction at atmospheric pressure taking only about 14 days.

Suitable vessels for these measurements are afforded by the strong glass bottles used to hold sulphurous acid. A screwed brass collar was cemented to the neck, and to this a brass T-piece was secured by a gas-tight union. The glass nozzle for supporting the bubble was cemented into the vertical arm of the T-tube, and sealed to a thick glass bulb above bent over horizontally to hold some soap solution. The gas used was admitted by the valved horizontal arm of the T-piece, a hole being made at this level into the inner glass tube to give access through the nozzle, which had a diameter of about 1 cm. (Fig. 39), just within its lower end a constriction was formed. The apparatus was tested and found tight under 10 atmospheres pressure.

The pressure was first adjusted to about 6 atmospheres, and a drop of soap solution was decanted into the constriction; on admitting more gas a bubble was expanded on the nozzle and the pressure thereby raised to 6½ atmospheres. The black stage then developed very much as usual, and the gas transference was determined by periodic measurements of the contraction.

FIG. 39.

Table V gives the rate of transference obtained in hydrogen at 6½ atmospheres compared with the values at 1 atmosphere. The numbers given are calculated for diameters of 4, 6 and 8 cm. The second column gives the internal excess pressure P of the soap bubble (in mm. of water) measured at atmospheric pressure. The proportion F of this to the total pressure in the bubble vessel is shown in the third column (in units of 10^{-6}) both for 1 atmosphere and 6½ atmospheres. The observed rates of gas transference R are similarly shown in the fourth column.

Thus it may be said that the longevity is increased in the proportion of the numbers given in the last two columns, in this case, approximately as the square roots of the relative pressures under which the bubbles were blown.

TABLE V.

Diameter cm.'s	P mm.'s H_2O	$F \times 10^{-6}$		R c.c.'s	
		(a) 1 atm.	(b) 6.5 atm.	(a) 1 atm.	(b) 6.5 atm.
4	0.330	32.16	4.80	0.22	0.0825
6	0.220	21.44	3.20	0.14	0.041
8	0.166	16.08	2.40	0.10	——

For experimental assistance I have to thank W. J. Green, B.Sc., and for reading the proofs and checking the calculations I am indebted to J. D. H. Dickson, M.A., Senior Fellow of Peterhouse College, Cambridge.

Specific Gravity of Orthophosphoric Acid. N. P. Knowlton and H. C. Mounce (*Jour. Ind. and Eng. Chem.*, 1921, xiii, 1157–1158) have determined the specific gravity of aqueous solutions of orthophosphoric acid at 25° C. compared to water at 25° C. The twenty-four solutions used by them ranged from 3.39 per cent. orthophosphoric acid with a specific gravity of 1.0187 to 90.26 per cent. orthophosphoric acid with a specific gravity of 1.7558. From the plotted curve of their results they have prepared a table, giving the specific gravity of aqueous solutions of orthophosphoric acid for each per cent. of the acid from 1 per cent. to 91 per cent., both inclusive.

J. S. H.

Separation of Sucrose from Glucose. Leon A. Congdon and Charles R. Stewart, of Syracuse University (*Jour. Ind. and Eng. Chem.*, 1921, xiii, 1143–1144), have tested the solubility of these two sugars in various organic solvents, using an ordinary Soxhlet extraction apparatus. The sugar was placed in the paper thimble, and the solvent was heated for five hours. When one gram of dry sugar and 100 c.c. of ethyl acetate were used, glucose was almost completely extracted, while sucrose was but slightly affected. When a mixture of equal parts of glucose and sucrose was used, an almost complete separation of the two sugars was obtained. On cooling its solution in ethyl acetate, glucose (dextrose) separated in the crystalline form.

J. S. H.

Proposed Translation of Helmholtz's "Handbuch der physiologischen Optik." James P. C. Southall, President of the Optical Society of America, invites subscriptions to a fund to translate into English the last edition of Helmholtz's great work, which still remains the leading authority in the field. In addition to the value of the work in a form in which its text will be accessible to many who do not read the original language, the publication will neatly mark the centennial anniversary of the birth of the great scientist, whose influence has been felt as deeply in modern scientific thought as that of any of his distinguished contemporaries. It is estimated that the cost of translating and publishing the volume will be at least $5000. Contributions in any amount may be sent to Adolph Lomb, treasurer, care of the Bausch and Lomb Optical Company, Rochester, New York. A subscription of not less than $15 will entitle the subscriber to a copy of the complete work.

H. L.

THE CRYSTAL STRUCTURES OF THE COMMON ELEMENTS.*

BY

ALBERT W. HULL, Ph.D.

Research Laboratory General Electric Company, Schenectady, N. Y.

INTRODUCTION.

By crystal structure is meant the exact relative location of and distances between atoms in solid bodies. The crystal structure of a substance is known only when an exact model of it can be constructed to scale, showing all the atoms in their positions. A knowledge of the shape or size of the atoms is not generally included in the definition, but the experiments on crystal structure give some information regarding size and shape, which will be briefly discussed. Many experiments now in progress are sure to yield more evidence on this subject.

The microscope by which these atomic measurements are made is an X-ray instrument, constructed on the principle of the spectroscope, rather than the microscope. It is used to measure the distance between planes of atoms, in exactly the same way as a grating spectroscope is used to measure, by means of a known wave-length of light, the distances between the lines of an unknown grating. In the case of the X-ray spectroscope the registration must, of course, be photographic or electrical (ionization), not optical; except when sufficient intensity is available to make a fluorescent screen luminous, and so indirectly allow visual reading. The fundamental difference between this X-ray spectroscope and the ordinary spectroscope is that the X-ray grating is a crystal which is three-dimensional instead of two-dimensional, and has to be placed at exactly the right angle in order to operate. This is the cause of the special technique of X-ray crystal analysis, which will be briefly outlined below.

The X-ray spectroscope measures the distance between planes of atoms, in any desired direction. This is all that is needed, in simple cases, for the construction of the crystal model. For it is

---

* Presented at a meeting of the Section of Physics and Chemistry held Thursday evening, November 10. 1921.

evident that if three sets of planes can be constructed, in different directions, each set including all the atoms in the crystal, their in tersections will give all the points at which atoms can be located. The only question remaining is *how many* atoms are located at each point. If the density of the crystal requires that this number cannot be greater than one, and the symmetry requires that every point shall be occupied by an atom, *i.e.,* that the number cannot be less than one, then the analysis is complete. This is the case with all the pure elements analyzed thus far, except bismuth. Although three sets of planes are sufficient, many more are usually observed in order to strengthen the evidence and increase the precision.

In case more than one atom, *i.e.,* a group molecule, is located at some of the points, as is probably the case with electronegative elements like sulphur and selenium, and with most compounds, the X-ray spectroscope is able to give evidence of this fact by the *intensity* of the diffraction images. Such intensity measurements were used in the analyses of several of the compounds recorded in Table 2. It is from these intensity measurements, also, that we hope for the greatest evidence regarding the shape and size of atoms.

SCOPE.

X-ray crystal analysis is still in its infancy. Only 35 of the 87 known elements have as yet been analyzed, and four of these analyses, Li, Bi, Sn and Ce, are incomplete. The 31 complete analyses include nearly all the common metallic elements. These analyses are complete only in the limited sense that the arrangement of the atoms and the distances between them have been determined, with an accuracy of about ½ per cent., at room temperature. They are incomplete with respect to polymorphic arrangements that appear at other temperatures, and are of course incomplete in the sense that they do not tell all that can and will be learned from X-ray crystal analysis about these elements, especially the shape and structure of the atoms. Investigations to obtain further information of this kind are already in progress in many laboratories, notably those of the pioneers of X-ray crystal analysis, W. H. and W. L. Bragg.

In addition to these 34 elements, 42 binary compounds have been analyzed, and 10 more-complicated ones.

In spite of the small number of these analyses the information

which they furnish is so closely related to other chemical and physical properties of atoms that it cannot fail to be useful. The extent to which it is used will depend upon its availability. It is the purpose of the present paper to collect and summarize this data in the hope of making it more available.

METHODS.

The methods of X-ray crystal analysis have been so well and so frequently described that only a summary need be given here, with a brief discussion of some of the more recent developments. For details the reader is referred to the excellent description by the originators of X-ray crystal analysis, W. H. and W. L. Bragg,[1] and the recent articles of Debye and Sherrer [2] and the author.[3]

The principle underlying all the different so-called methods of X-ray crystal analysis is the same. It consists in observing the angles at which X-rays of a known wave-length are reflected by the planes of atoms in the crystal, and so calculating the distance between these planes; and then constructing a model having these planar spacings. The different methods are occasioned by different ways of mounting the crystal, which necessitates different procedure in interpreting the results.

A. Laue Method.—A *single* crystal, which may be very small, is mounted in a *known* orientation, and illuminated with a narrow beam of *white X light, i.e.,* a beam containing all wave-lengths within a certain range. A photographic plate placed behind the crystal registers, in its centre, the primary beam which has passed through the crystal, and around this central image a large number of small spots. Each of these spots is caused by the reflection of some wave-length in the primary beam by one of the sets of planes in the crystal.

In order to interpret such a photograph it is necessary to determine what set of planes and what wave-length corresponds to each spot. These calculations are exceedingly laborious. The first crystal analyses by W. L. Bragg were made by this method, but it has led to only a few complete analyses. It is especially suited to qualitative investigation, because of the simplicity and speed with

---

[1] " X-rays and Crystal Structure," by W. H. and W. L. Bragg. G. Bell and Sons, London.

[2] Debye and Sherrer, *Physik Z.,* 17, 277, 1916; 18, 291, 1917.

[3] Hull, *Phys. Rev.,* 10, 661, 1917; 17, 571, 1921.

FIG. 1.
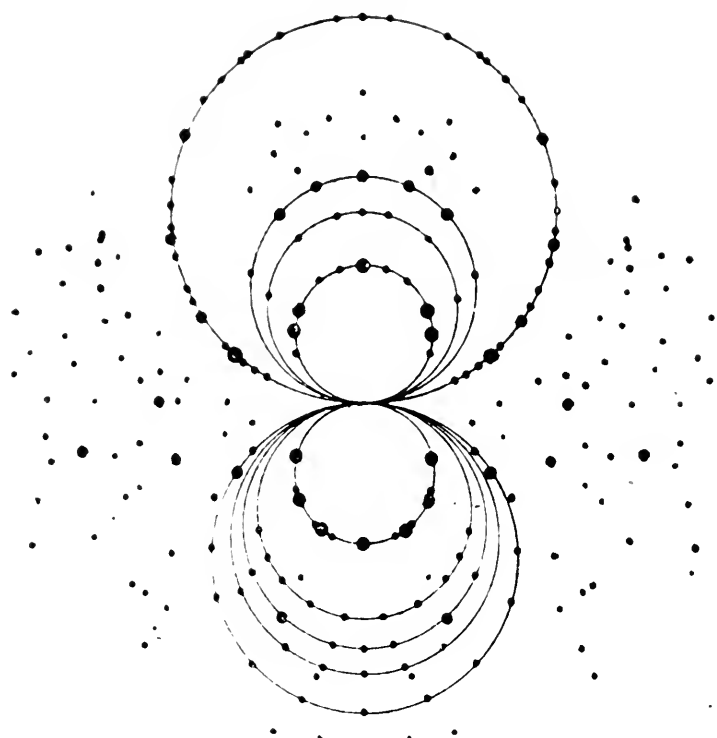
Stereographic projection of Laue spots of adularia (001).

FIG. 2.
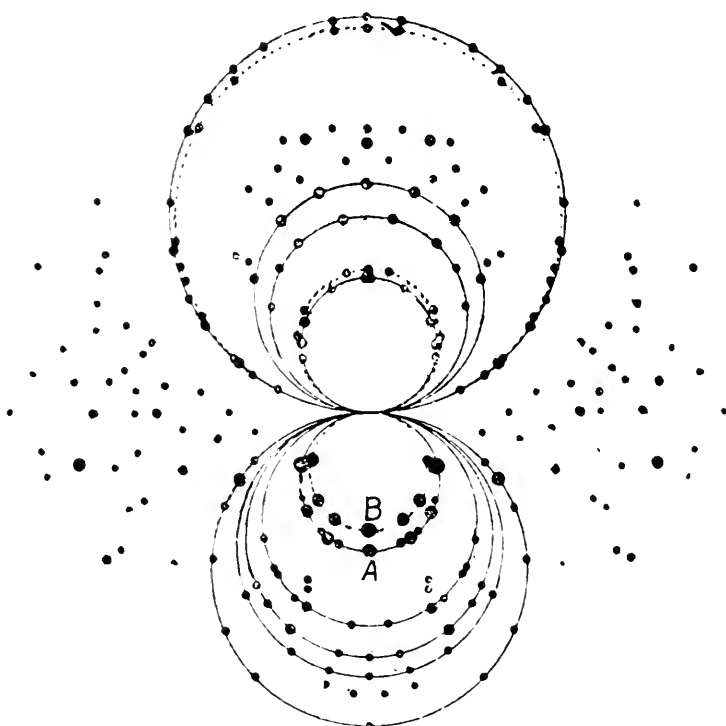
Stereographic projection of Laue spots of moonstone (001).

which the photographs can be taken. For example, Figs. 1 and 2 represent stereographic projections of Laue patterns[4] of two closely related feldspars, adularia and moonstone respectively. They show that moonstone consists of two distinct monoclinic lattices, corresponding to two different kinds of solid solution, whereas adularia is a single homogeneous solid solution.

Quite recently Wyckoff[5] has applied the Laue method with great thoroughness to the analysis of several crystals. It is prob-

FIG. 3.
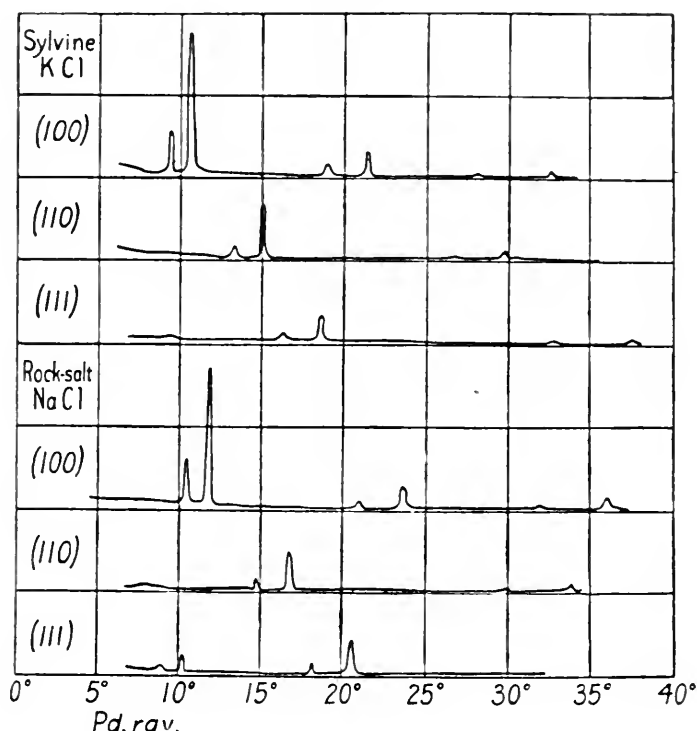
Reflection of Pd. X-rays from different planes of sylvine and rock salt.

able, however, that the use of this method will be mainly restricted to supplementing other methods.

B. Bragg Method.—A narrow pencil of monochromatic X-rays falls on the face of a single crystal, and is reflected to an ionization chamber or photographic plate. Crystal and ionization chamber are rotated until the reflecting angle is found, first for one face and then another. The angle and intensity

---

[4] These figures are taken from a review of a paper of S. Kozu by Tutton in *Nature*, 108, 352, 1921.

[5] Wyckoff, *Am. J. Sci.*, 50, 317, 1920; *Phys. Rev.*, 16, 149, 1920; *J. Am. Chem. Soc.*, 42, 1100, 1920.

of reflection are recorded for each face, as shown in Fig. 3.[6] Since both the wave-length and the reflecting face are known, the model can be constructed at once for simple lattices; and complex structures can be interpreted if the intensity measurements are accurate.

This method, by far the simplest, is applicable only when single perfect crystals are available. Unsuspected twinning or distortion of the crystal will lead to false conclusions. In these cases the powder method offers a very simple check. There are a great many perfect crystals still unstudied, whose successful analysis awaits only time and experience in the interpretation of intensity of reflection.

C. Powder Method.—Instead of observing the reflections from different crystal faces one at a time, as in the Bragg method, one may register them all simultaneously on a photographic plate,

FIG. 4.

Powder diffraction pattern of rock salt.

by using a large number of small crystals, oriented at random. If the number of these small crystals is sufficiently large every possible reflecting position of the large crystal in the Bragg method will be represented simultaneously by one or more of the small crystals. The resulting photograph will contain, on a single film, all the reflections that could be obtained from the different faces of a single crystal. For example, a powder diffraction photograph of rock salt would be the equivalent of superimposing the three lower rows of Fig. 3, plus several more rows not given in the figure. Such a photograph is shown in Fig. 4.[7]

It is obvious that the reflections from different faces are so mixed in the photograph that one cannot tell, as in the Bragg method, which one belongs to each particular face. This makes

---

[6] From " X-rays and Crystal Structure," p. 89.

[7] Each of the reflections plotted in Fig. 3 consists of a pair of lines, one strong and one weak, due to the fact that the source of X-rays was not monochromatic, but consisted of two wave-lengths. The source used for Fig. 4 was truly monochromatic, the weaker component having been absorbed by filters. Hence only the strong reflections of Fig. 3 appear in Fig. 4.

it more difficult to construct the model. On the other hand, the powder photograph cannot lie. Twinning and distortion have no effect on it. Every set of planes in the crystal whose spacing is large enough to come within the limits of the photograph is represented by a line.

The construction of the model, though more difficult than with the Bragg procedure, is still very easy for simple substances. In the Bragg procedure the spacing of each set of planes is known from the experimental data, and the model is constructed with these definite dimensions. In the powder procedure the whole group of spacings, from the largest down to a specific value is known, and one seeks a model whose whole pattern of spacings fits the observed pattern. The fit must be exact, both in position and intensity. A single extra line, unless accounted for by a demonstrable impurity, invalidates the solution.

The process of taking and interpreting the powder photographs has been greatly simplified. The X-ray tube may be made to operate without attendance, and to take several photographs simultaneously. Fig. 5 shows such an equipment, adapted to operate from a lamp socket, to run continuously day and night without attention, and to take fifteen pictures simultaneously.[8] The operator is automatically protected from both X-rays and voltage, the transformer and high tension connections being entirely internal and the case grounded. The investigator is thus free to concentrate his attention upon the more strictly scientific parts of the investigation, viz., the preparation of the material to be studied, and the reading and interpretation of the results.

The mounting of the material is very simple. It is reduced to fine powder by crushing or filling, placed in a thin glass tube 1 mm. in diameter, and the tube inserted in the slot provided for it in the cassette. When more convenient the powder may be mixed with a small amount of organic binder and spread on a narrow strip of paper or celluloid, and thin strips of metal or wires of the material to be tested may be used instead of powder in special cases. Massive lumps and moulded blocks have also been used with good results, the block being so mounted as to reflect the rays from its face. In the case of high atomic weight materials it is desirable

---

[8] A detailed description of this equipment is given by W. P. Davey in the November number of the *J. Optical Soc. of America.*

to mix the powder with some light amorphous substance, so as to reduce the total absorption of the rays, in passing through the sample, to about 50 per cent. absorption. Flour and corn starch have been satisfactorily used for this purpose.

FIG. 5.
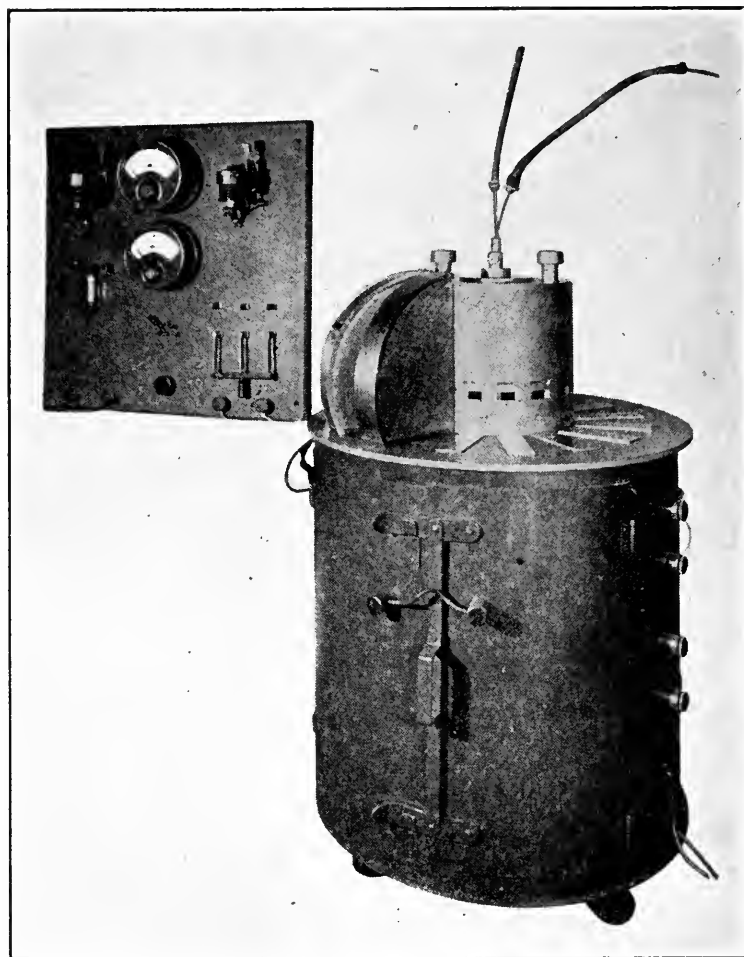
Apparatus for X-ray powder diffraction photography.

The reading of the film can be greatly facilitated when once the apparatus has been standardized. With a given wave-length and radius of film the planar spacings corresponding to the different lines on the firm are a function only of the distances of the lines from the trace of the undeviated beam. This function may therefore be laid off once for all on a scale, which may be used to read off planar spacings in angstrom units directly from the film, as shown in Fig. 6; or the scale may be laid off on a template, which

may be fastened beneath the film in the cassette, and so photograph a scale of angstrom units on the film during exposure, as in Fig. 7.

The interpretation of the powder patterns in the case of simple substances is straight forward and easy when the crystallographic system and axes of the substance are known. For complex substances the intensities of the lines must be measured. This can be

FIG. 6.
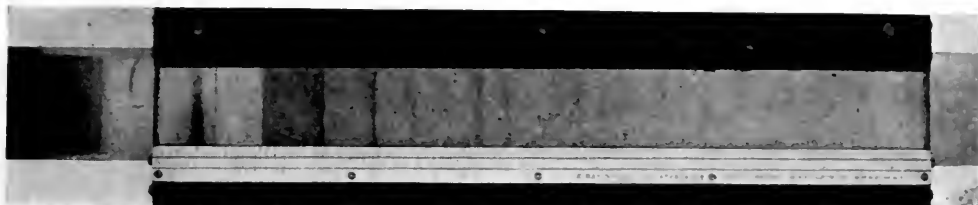
Scale for reading crystal spacings directly from powder diffraction pattern.

done with an accuracy of about five per cent. by an optical pyrometer or a photo-electric photometer, in terms of a series of steps of known ratios, photographed on one end of the film by the main monochromatic beam, through a stepped filter. These steps are produced by the same wave-length and in the same length of time as the lines with which they are to be compared. Hence the

F.G. 7.
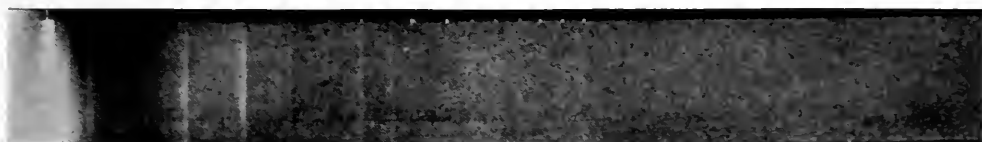
Scale of crystal spacings photographed on powder diffraction pattern.

intensity measurements are independent of the law of blackening of the film and the development, except in so far as these may vary from point to point along the film. Quite recently W. H. Bragg has shown [9] that the powder reflections can be measured with an ionization chamber, in the same way as the reflections from a single crystal. This allows still greater accuracy in the measurement of intensities.

When there is no reliable crystallographic data about the substance under investigation the interpretation is in general very laborious. The procedure is to make guesses, and check them one

---

[9] W. H. Bragg. *Proc. Phys. Soc. London*, **33**, 222, 1921.

by one. When once the right guess is made its correctness is at once obvious, but an indefinite number of wrong guesses may have to be tried before finding the right one. Systematic mathematical methods of procedure have been suggested by Runge [10] and Johnsen and Toeplitz,[11] but have so far been applied only to the case of graphite. It is to be hoped that these methods will be found capable of application to crystals of low symmetry.

FIG. 8.
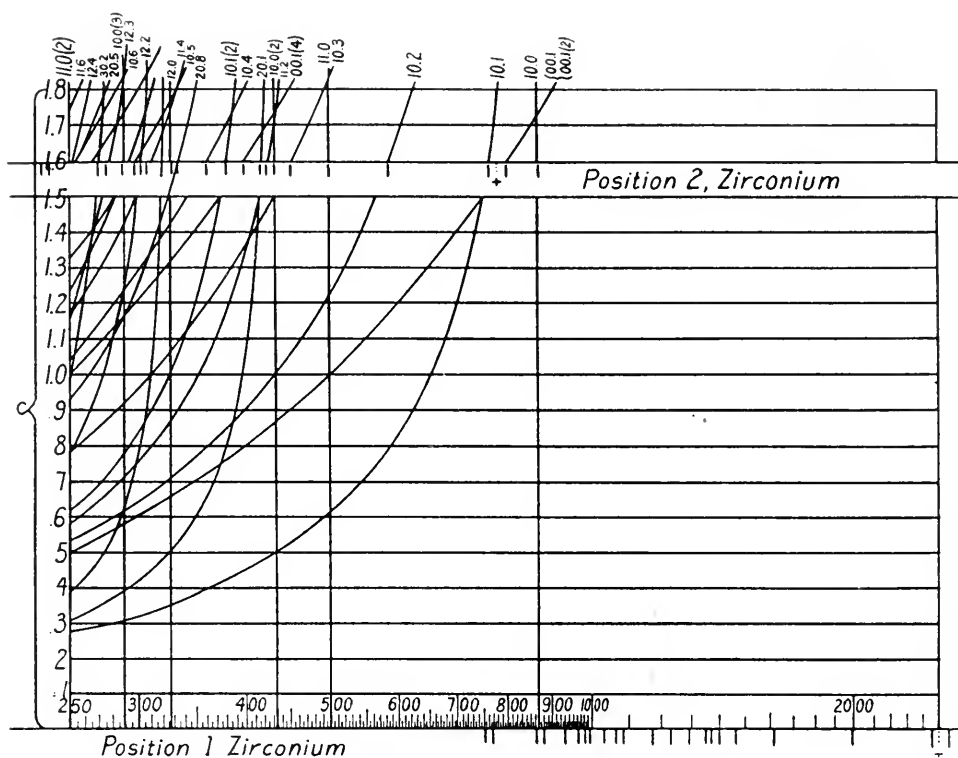
Graphical analysis of zirconium.

For uniaxial crystals the process of guessing may be greatly simplified by the use of plots, showing the possible planar spacings as a function of the axial ratio of the crystal.[12] The observed spacings are laid off on a strip of paper, which is moved systematically over the plot, comparing its pattern of experimental lines with the theoretical ones of the plot for each axial ratio. The process is one of guessing and check, as before, but the checking is

[10] Runge, *Phys. Z.,* **18,** 509, 1917.

[11] Johnsen and Toeplitz, *Phys. Z.,* **19,** 47, 1918

[12] Hull and Davey, *Phys. Rev.,* **17,** 549, 1921.

facilitated so that an entire crystal system may be gone over in a few minutes. Figs. 8 and 9 show the application of this method to zirconium and osmium.

The application of graphical analysis to crystal systems having more than one variable parameter, *i.e.*, to the orthorhombic, monoclinic, and triclinic systems, presents more difficulties, and a satisfactory method has not yet been found.

FIG. 9.
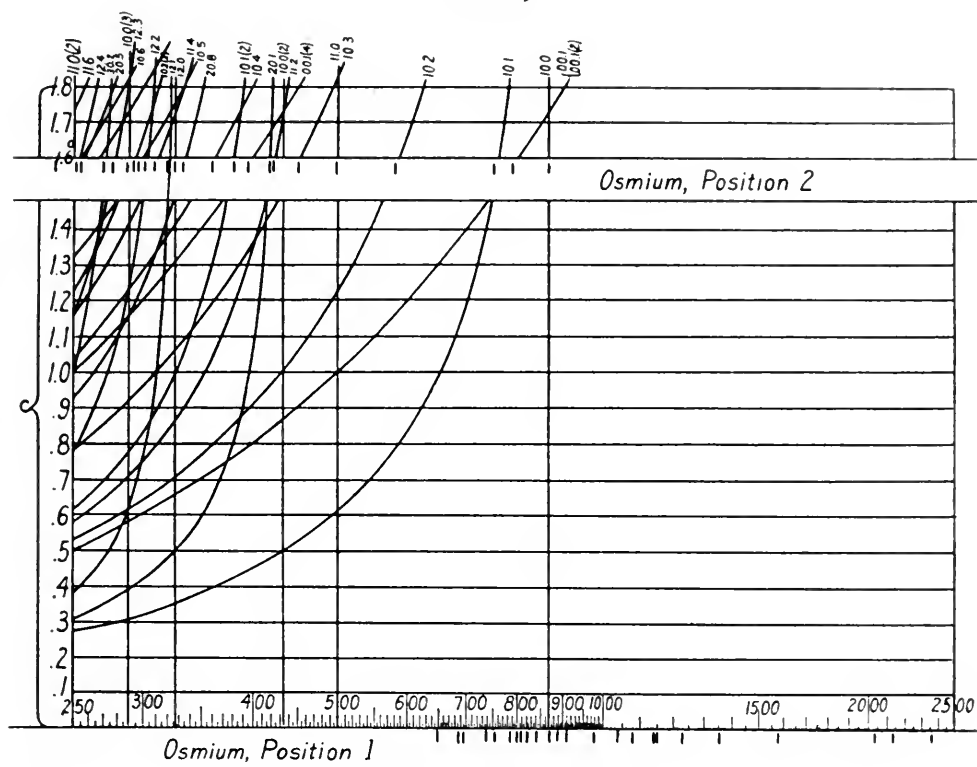
Graphical analysis of osmium.

EXPERIMENTAL RESULTS.

The results of the analyses of elementary substances that have been made thus far are summarized in Table 1, the elements being arranged in the order of atomic weights. The headings are self-explanatory, except for the two values given for the atomic diameter of some elements. These are the distances to the nearest atoms in the pyramid planes and basal planes respectively, corresponding approximately to the major and minor axes respectively of the solid ellipsoids of revolution which, if closely packed, would give the observed arrangement. The two values are inserted as a

TABLE I.
Crystal Structures of Elements.

Substance	Crystal Structure		Latitce Constant Side of Elementary Cube or Hexagonal.	Closest Approach of Atoms	Authority
	Type of Lattice	Axial Radio			
Lithium........	Body-centered cube		3.50	3.03	Hull[1]
Carbon {diamond	Tetrahedral cubic		3.56	2.06	Bragg[2]
{graphite	Hexagonal	2.75	2.47	1.50	{Debye[3] {Hull[1]
Sodium........	Body-centered cube		4.30	3.72	Hull[1]
Magnesium.....	Hexagonal	1.624	3.22	3.22	Hull[1]
Aluminium.....	Face-centered cubic		4.05	2.86	{Hull[1] {Sherrer[4]
Silicon........	Tetrahedral cube		5.43	2.35	{Debye[5] {Hull[1]
Calcium........	Face-centered cubic		5.56	3.93	Hull[6]
Titanium.......	Hexagonal close-packed	1.59	2.97	{2.90 {2.96	Hull[7]
Vanadium......	Body-centered cubic		3.04	2.64	Hull[8]
Chromium......	Body-centered cubic		2.895	2.508	Hull[9]
Iron..........	Body-centered cubic		2.86	2.48	Hull[1]
	Face-centered cubic		3.60	2.54	{West- {gren[10] {Bain[19]
Cobalt........	Face-centered cubic		3.554	2.514	Hull[9]
	Hexagonal close-packed	1.633	2.514	2.514	Hull[9]
Nickel.........	Face-centered cubic		3.540	2.505	Hull[1,9] Bohlin[11]
Copper........	Face-centered cubic		3.60	2.54	Bragg[12]
Zinc..........	Hexagonal close-packed	1.860	2.670	{2.920 {2.670	Hull[9]
Zirconium......	Hexagonal close-packed	1.59	3.23	{3.18 {3.24	Hull[7]
Molybdenum...	Body-centered cubic		3.143	2.720	Hull[9]
Ruthenium.....	Hexagonal close-packed	1.59	2.686	{2.640 {2.686	Hull[9]
Rhodium.......	Face-centered cubic		3.820	2.700	Hull[9]
Palladium......	Face-centered cubic		3.950	2.795	Hull[9]
Silver.........	Face-centered cubic		4.060	2.876	Vegard[13]
Cadium........	Hexagonal close-packed	1.89	2.960	{3.28 {2.96	Hull[9]
Indium........	Face-centered tetragonal	1.06	4.58	{3.33 {3.24	Hull[9]
Tin (gray)......	Tetrahedral cubic		6.46	2.80	Bijl[14]
Antimony......	Rhombohedral hexagonal	2.647	4.28	{2.87 {3.02	James[15]
Cerium........	Hexagonal close-packed	1.62	3.65	3.64	Hull[7]
	Face-centered cubic		5.12	3.64	
Tantalum......	Body-centered cube		3.272	2.833	Hull[9]
Tungsten.......	Body-centered cubic		3.150	2.726	{Debye[16] {Hull[9]
Osmium........	Hexagonal close-packed	1.59	2.714	{2.66 {2.72	Hull[7]
Iridium........	Face-centered cubic		3.805	2.690	Hull[9]
Platinum.......	Face-centered cubic		3.930	2.780	Hull[9]
Gold..........	Face-centered cubic		4.08	2.88	Vegard[17]
Lead..........	Face-centered cubic		4.92	3.48	Vegard[17]
Bismuth........	Rhombohedral hexagonal		4.54	{3.11 {3.47	James[18]
Thorium.......	Face-centered cubic		5.04	3.54	{Bohlin[11] {Hull[7]

record of experimental results, independent of what the actual shape of the atoms may be.

The thirty-five elements in Table 1 represent five different types of atomic arrangements. They are designated respectively as face-centered cubic or cubic close-packed, body-centered cubic, tetra-hedral cubic or diamond type, hexagonal close-packed, and rhombohedral.

The most common arrangement is the face-centered cubic type.

FIG. 10a
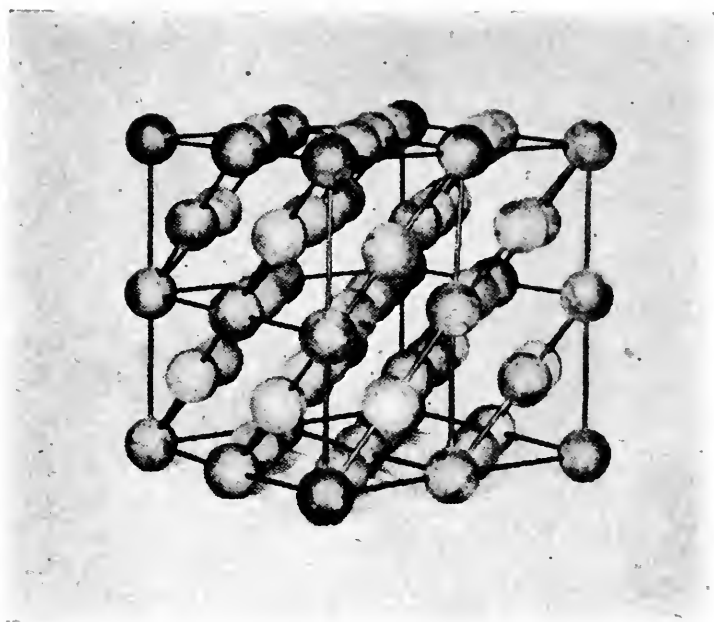
Model of face-centered cubic arrangement.

This arrangement is especially interesting because it is one of the two alternative arrangements which equal solid spherical balls assume when put into a box and shaken until they are packed as closely as possible. This arrangement is shown in Figs. 10a and 10b. The closest packed arrangement of spheres is obviously that which gives the maximum number of contacts between each sphere and its neighbors. In Fig. 10b each sphere touches twelve others.

Fifteen elements have their atoms arranged in this face-centered cubic or cubic close-packed arrangement; and it is worthy of note that they are all metals and all ductile. The ductility may reasonably be ascribed to the arrangement, and one may general-

ize tentatively as follows: Any substance which crystallizes face-centered cubic will be ductile.

For the purpose of visualizing this relation the type of lattice may be connected with the shape of the atom. The tendency of the atoms of certain substances to arrange themselves like closely packed solid spheres can best be pictured as due to the fact that the electrons in their outer shells are so symmetrically distributed and so closely coupled together [13] as to present toward other atoms an essentially rigid spherical shell, with very weak residual localized forces. These atoms are held together in the solid crystalline

FIG. 10*b*.
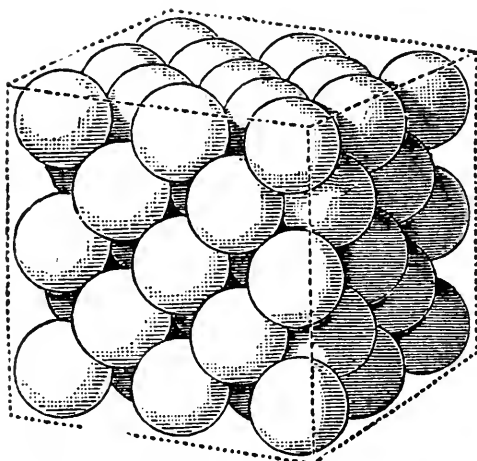
Cubic close-packing of solid spheres (face-centered cubic arrangement).

state, not by the sharing of electrons or secondary valence forces, but by free electrons wandering at random between the atoms, occupying on the average fairly definite positions. These free electrons are the electrons that are superfluous to the formation of the stable spherical shells; for example, in Cu, Ag and Au, the single electron which is so easily lost in chemical reactions is certainly less firmly bound than the others, and must be superfluous to the formation of a stable shell. These elements will have one free electron for every atom, and the free electrons will occupy, on the average, the positions of the chlorine ions in sodium chloride. In Mg, Zn and Cd there are presumably two free electrons per atom, with average positions the same as the fluorine atoms in CaF_2.

The presence of free electrons in the lattice accounts at once for the mobile cohesion and the conductivity. Whether a face-

[13] Cf. Born, *Verh. d. deut. physk. Gesell.*, **20**, 230, 1918.

centered cubic type of lattice is possible without free electrons or ions to hold it together must remain questionable until the remaining elements have been examined. Such a substance would probably be non-metallic.

There is one other element, indium, which should be classed with the cubic close-packed metals, though its structure is not face-centered cubic but face-centered tetragonal. The arrangement is the same as cubic close packing except that it is stretched six per

FIG. 11a.
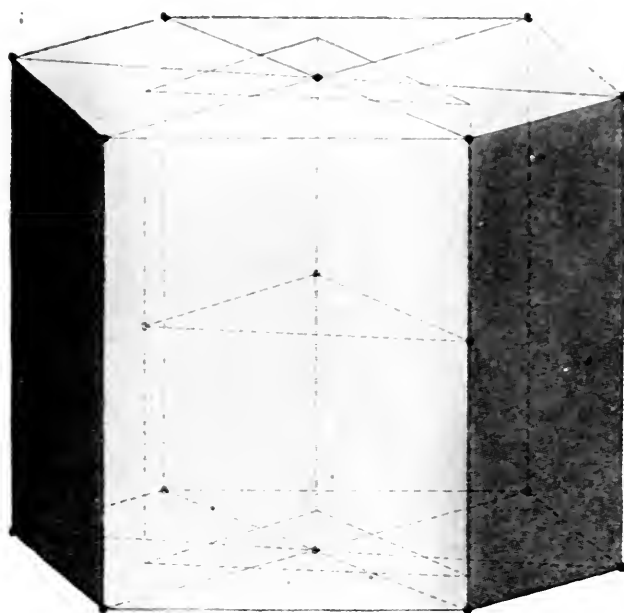
Model of hexagonal close-packed arrangement.

cent. in the direction of one of the cubic axes. This is exactly the arrangement that eggs would assume if packed as closely as possible. The indium atom may therefore be pictured as having a rigid outer shell of electrons in the form of an oblate spheroid, with major axis 1.06 times the minor axis.

The next most common type is the *hexagonal close-packed* arrangement. It is the second of the two alternative close-packed arrangements which equal hard spheres assume when put into a box and shaken. It is equally close-packed with the cubic close-packed arrangement, each being derivable from the other by a simple shear. This arrangement is shown in Figs. 11a and 11b. Each atom is surrounded, as in cubic close packing, by 12 nearest neighbors, all equidistant and uniformly spaced, but with slightly different arrangement, giving to the crystal an hexagonal instead

of cubic symmetry.   It is an instructive pastime to study these
two close-packed arrangements of spheres with a few small balls,
such as are used for ball bearings.

Nine elements, all metallic, crystallize with the hexagonal close-
packed arrangement.   Only three of these, *viz.,* Mg, Co and Ce,
have the *true* close-packed arrangement of spheres, and two, Co
and Ce, appear to exist in both the cubic and hexagonal close-

FIG. 11*b.*
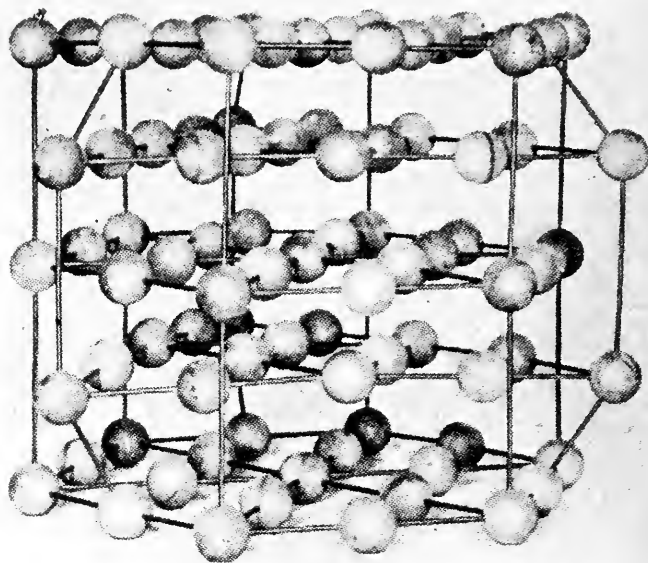
Model of hexagonal close-packed arrangement.

packed arrangements.   It may be predicted that the passage from
one of these forms to the other will not be accompanied by any
measurable evolution of heat, since the potential energies of the
two arrangements are identical for truly spherical atoms.

The remaining six hexagonal close-packed elements, are
slightly elongated or shortened in the direction of the hexagonal
axis.   Zinc is elongated 14 per cent., cadmium 16 per cent.,
while Ru, Ti, Zr and Os are *shortened* 3 per cent.   These are
exactly the arrangements which solid prolate and oblate spheroids
would assume respectively, if packed as closely as possible, being
alternative to the corresponding face-centered tetragonal arrange-
ments.   It seems very probable that the outer electron shells of

these atoms actually are spheroidal in shape as indicated by their crystal structure.

Eight elements crystallize in a *body-centered cubic* arrangement, as illustrated in Fig. 12. Each atom is surrounded by eight others, in the direction of the eight cube corners. The atoms have been represented as cubes in order to bring out this fact. The arrangement is that which would result from cubical atoms holding on to each other by their cube corners, by sharing electrons, for

FIG. 12.
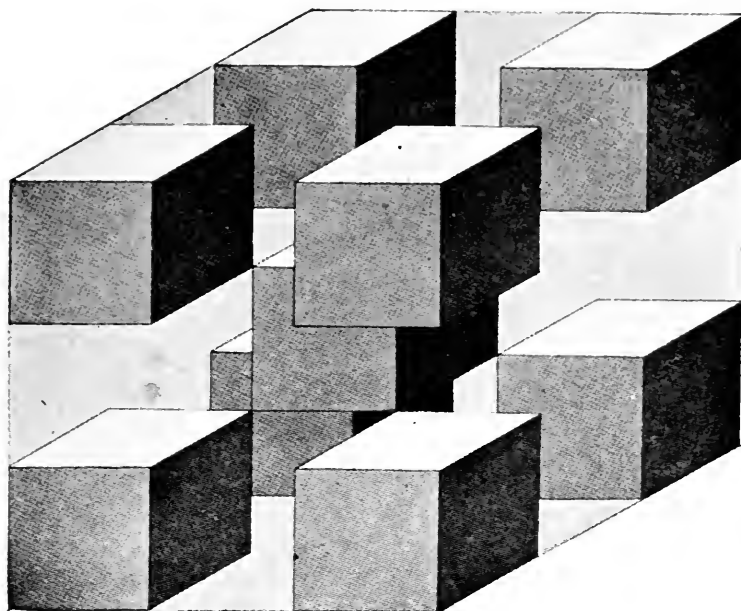
Body-centered cubic arrangement.

example. It might also be the result of an octahedral shape for the outer electron shell of the atoms such as might be expected if the atom shell were composed of eight electrons rotating around the eight corners of a cube, as in Landé's model of Neon.[14]

Three elements, carbon (diamond), silicon, and gray tin, crystallize in the tetrahedral arrangement, represented by Fig. 13 (taken from Bragg's model of diamond). Each atom is symmetrically surrounded by four others, and in this case there is strong chemical evidence that the atoms are really tetrahedral in shape.

---

[14] Landé. *Verh. D. Phys. Ges.*, **21**. 2. 1919.

Finally, there are three elements, carbon (graphite), antimony, and bismuth, whose crystalline arrangements are composed of two intermeshed rhombohedral lattices. Graphite may be described as a greatly stretched diamond structure, in which the pairs of planes perpendicular to the cube diagonal are spread apart, from 2.05 angstroms to 3.40Å, making the crystal exceedingly weak and cleavable parallel to these planes. The unit of structure of antimony and bismuth, as given by James and Tunstall [15] is represented in Fig. 15. These two elements are especially interesting

FIG. 13.
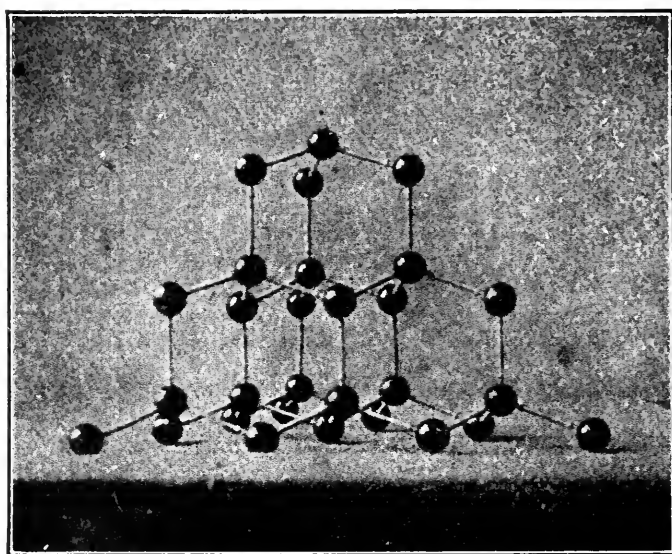
Tetrahedral or diamond arrangement.

because their structure is very nearly simple cubic, each atom being surrounded by *six* nearest neighbors (as in Fig. 16, which represents the structure of rock salt). No other examples of this kind have been found among elements. In Fig. 15 the full lines represent the slightly distorted cube which is the unit of structure, its angle being changed from 90° to 92°53′ in the case of antimony; and the dotted lines the additional slight shift, in the direction of the hexagonal axis, which must be given to half of the atoms. These two elements require more study before their very unusual physical properties can be correlated with their crystal structure.

[15] James and Tunstall, *Phil. Mag.*, 40, 233, 1920.

CRYSTAL STRUCTURE AND THE PERIODIC TABLE.

In order to show the relation of crystal structure to chemical properties of the elements, the data in Table 1 have been represented graphically on a Mendelejeff chart, in Fig. 15. This chart brings out some striking relations. *Elements in the same vertical column all have the same crystal structure.* The only exceptions are iron in group 8, which is in many ways an exceptional ele-

FIG. 14.

Arrangement of atoms in antimony.
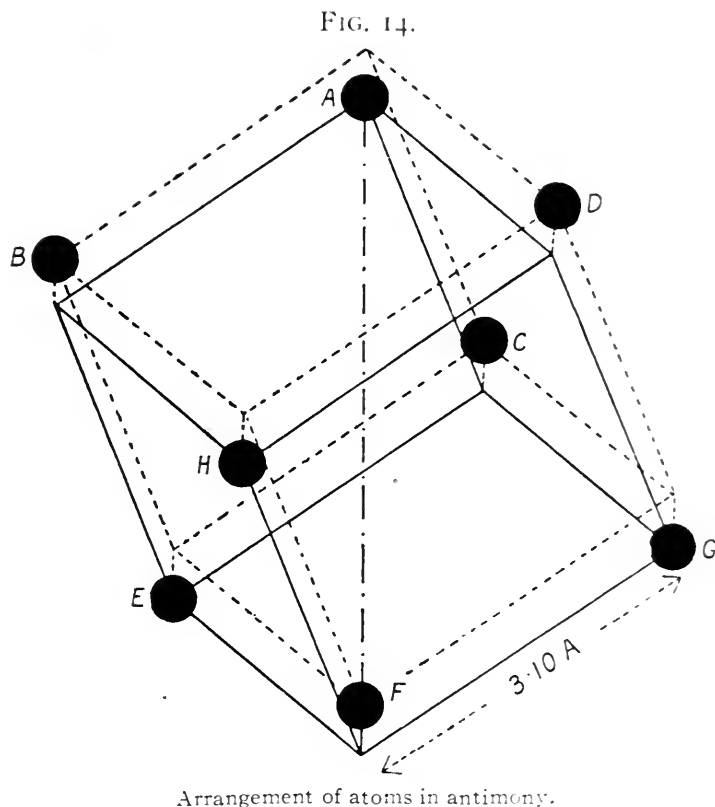
ment; and lead and thorium in group 4, where the tetrahedral property that is so strong in the low atomic number elements (C and Si) becomes less and less pronounced with increasing atomic number,[16] and appears to be completely lost in the spherical atoms Pb and Th.

The face-centered cubic elements are found mainly in the right-hand columns of groups 1 and 8, that is in the *middle of the long periods.* The elements immediately preceding and following these middle elements, *viz.,* the left column of group 8 and right column of group 2, are hexagonal close-packed. Still lower in the

[16] Hull, *Phys. Rev.,* **18,** 88, 1921.

Fig. 15.

MENDELEJEFF'S PERIODIC SYSTEM OF THE ELEMENTS
Containing Atomic Weights, Atomic Numbers and Isotopic Radioactive Elements

Group 0	Group 1 E_2O	Group 2 EO	Group 3 E_2O_3	Group 4 EO_2 EH_4	Group 5 E_2O_5 EH_3	Group 6 EO_2 EH_2	Group 7 E_2O_7 EH	Group 8 EO_4
He 3.99 (2)	H 1.008 (1) — C Cube Li R 6.94 (3) 1.51	Be* 9.1 (4)	B 11.00 (5)	Rhomb C=2.75 R=0.75 — C 12.00 (6) — Dia R=0.77	N 14.01 (7)	O 16.00 (8)	F 19.0 (9)	
Ne₁ 20.2 Ne₂ (10)	Na C.Cube R=1.86 22.99 (11)	Hex Close C=1.633 R=1.61 Mg 24.32	F C Cube R=1.43 Al 27.1 (13)	Dia R=1.17 Si 28.3 (14)	P 31.04 (15)	S 32.07 (16)	Cl 35.46 (17)	C Cube R=1.234 Hex Close R=1.257 Fe F C Cube Co Ni 55.84 58.97 58.68 (26) (27) (28)
Ar 39.10 (18)	K 39.10 (19)	Ca F C Cube R=1.96 40.07 (20)	Sc 44.1 (21)	Ti Hex Close C=1.59 R=1.45 48.1 (22)	V 51.0 (23)	Cr C.Cube R=1.254 52.0 (24)	Mn 54.93 (25)	
Kr 82.92 (36)	F C Cube R=1.27 Cu 63.57 (29)	Hex Close C=1.86 R=1.335 1.460 Zn 65.37 (30)	Ga 69.9 (31)	Ge C=1.59 R=1.62 72.5 (32)	As 74.96 (33)	Se 79.2 (34)	Br 79.92 (35)	C=1.59 Cube Cube R=1.343 R=1.350 R=1.357 1.320 Ru Rh Pd 101.7 103.9 106.7 (44) (45) (46)
	Rb 85.45 (37)	Sr 87.63 (38)	Yt 89.0 (39)	Zr Hex Close C=1.59 1.82 90.6 (40)	Cbt 93.5 (41)	Mo C.Cube R=1.360 96.0 (42)	– (43)	
Xe 130.2 (54)	F.C. Cube R=1.43 Ag 107.88 (47)	Hex Close C=1.89 R=1.490 1.646 Cd 112.40 (48)	In 114.8 (49)	Grey Dia R=1.537 Sn 119.0 (50)	Sb 120.2 (51)	Te 127.5 (52)	I 126.92 (53)	
Cs 132.81 (55)	Ba 137.37 (56)	La 189.0 (57)	F.C Tec C=1.06 R=1.62 1.66 Ce Hex Close F C Cube R=1.82 140.25 (58)	Rhomb C=1.324 R=1.51			

	Pr 140.6 (59)	Nd 144.3 (60)	— — (61)	Sa 150.6 (62)	Eu 152.0 (63)		Hex. F.C. F.C. Close Cube Cube C=1.59 R R R=1.36 1.345 1.390 1.33 Os Ir Pt 190.9 193.1 195.2 (76) (77) (78)
	Gd 157.3 (64)	Tb 159.2 (65)	Ho 163.5 (66)	Ds 162.5 (67)	Er 167.6 (68)	C Cube R=1.416	C Cube R=1.363	
	Tm₁ 168.5 (69)	Tm₁₁ (70)	Yb‡ 173.0 (71)	Lu 174.0 (72)	Ta 181.5 (73)	W 184.0 (74)	– (75)	

| | F.C. Cube R=1.44 Au 197.2 (79) | Hg 200.6 (80) | Tl 204.0 (81) | F C Cube R=1.74 Pb 207.16 (82) Ra D 210.2 Ac B 211.2 Th B 212.2 Th D₂ 208.2 Ra B 214.2 Ra D₂ 210.2 | Bi 205.0 (83) Ra E 210.2 Ac C 211.2 Th C₁ 212.2 Ra C 214.2 | Rhomb C= R= Ra F 210.2 Ac C₁ 211.2 Ac A 215.2 Th C₂ 212.2 Th A 216.2 Ra C₁ 214.2 Ra A 218.2 | – (86) | |

| Ac Em 219.3 Th Em 220.3 Ra Em 222.2 (86) | – (87) | Ac X 223.2 Th X 224.3 Ra 226.3 MesTh₁ 228.3 (88) | Ac 227.3 MesTh₂ 229.1 (89) | Rd Ac 227.3 Rd Th 228.2 Io 230.2 Th 232.2 F.C Cube R 177 Ux₁ 234.2 (90) | Ux₂ 234.2 (91) | U₁₁ 234.2 U₁ 238.2 (92) | | |

* Be = Gl
† Cb = Nb
‡ Neoytterbium = 173.5

X-203

Atomic Weights listed in Bold figures.
Atomic Numbers listed in *Italics* in parentheses.

Chart showing crystal structure of elements.

long periods, in *groups 5 and 6 (left), the elements are all centered cubic.* Finally, the elements of group 4 are all tetrahedral in the right column and hexagonal close-packed in the left.

An attempt to explain these periodic crystalline properties of the elements by the models of atomic structure recently proposed by Langmuir,[17] Bohr,[18] Bury,[19] and others, would be premature. It is clear from Fig. 15, however, that *crystal structure is the same periodic function of atomic number as is chemical behavior.* The

FIG. 16.
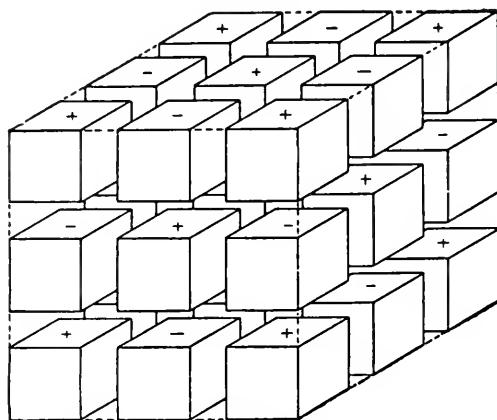
Arrangement of ions in rock salt.

two are presumably due to a common cause, which is certainly to be found in the number and configuration of electrons in the outer shell of the atom.

Whether this common cause is the sharing or exchange of valence electrons, or the shapes of the stable shells, must be determined by further experiments. The evidence here given indicates that the loss of valence electrons, which become *free electrons,* is the primary factor in the crystallization of elements; and that the shape of the remaining shell is the secondary factor, which determines the manner in which the atoms will pack together. The general principle is that the atoms tend to pack as closely as their shape and the number of free electrons will allow.

ATOMIC DIAMETERS.

The distances between nearest atoms in Table 1 may be called the effective diameters of the atoms in the elementary state. The question naturally arises: How near are these values to the actual

[17] Langmuir, *J. Am. Chem. Soc.*, **41**, 868, 1919.

[18] Bohr, *Nature*, **107**, 104, Mar. 24, 1921.

[19] Bury, *J. Am. Chem. Soc.*, **43**, 1602, 1921.

diameters of the outer shells of electrons? Many lines of evidence conspire to indicate that they are very close.

Richards [20] has frequently called attention of the fact that the compressibilities of substances are consistent with *elastic* spherical atoms of definite size. He has been able to calculate this size in the case of the alkali and halogen atoms, [21] from the compressibility and the contraction during chemical combination. These values are given in Table 2, for comparison with those obtained by other methods.

Rankine [22] has recalculated the dimensions of these atoms from viscosity measurements, taking account of the shape of the molecules, as suggested by recent atomic structure theory. He constructs a molecule of Cl_2 by combining two argon atoms, each of diameter given by viscosity measurements, with centres 2.05A apart, as found by Bragg from X-ray crystal measurements for chlorine. The theoretical viscosity of this molecule is found to agree quantitatively with the measured viscosity of chlorine, within the limit of experimental error. The same is found to be true for the other halogens. He therefore concludes that the diameters of the halogen and alkali atoms may be taken as equal to those of the adjacent inert gases, as determined by viscosity measurements. These values are given in Table 2.

Born and Landé, in a brilliant series of mathematical investigations, have succeeded in calculating the theoretical dimensions of lattices built up of positive and negative ions, like sodium and chlorine, held together by electrostatic attraction. They find that ring atoms built on the Bohr model give lattices for the alkali halogen salts of the right dimensions, but twice as compressible as the actual salts. Cubical atoms on the other hand, give both the right dimensions and the right compressibility, and the diameters of the outer shells of electrons come out to be very nearly equal to the distance between adjacent atoms,[23] that is, the electron shells are approximately in contact in these crystals. Landé's values of atomic diameter are also given in Table 2.

W. L. Bragg [24] has made a systematic study of the distances

[20] Richards, *J. Am. Chem. Soc.,* **36**, 2417, 1914.
[21] Richards, *J. Am. Chem. Soc.,* **43**, July, 1921.
[22] Rankine, *Proc. Roy. Soc.,* Feb., 1921.
[23] Landé, *Zeit. f. Physik,* **1**, 191, 1920.
[24] W. L. Bragg, *Phil. Mag.,* **40**, 169, 1920.

between adjacent atoms in all the substances for which data have been obtained by X-ray crystal analysis, and has shown that excellent agreement with the experimental values is obtained by assuming the atoms to be spheres of definite diameter, packed together as

TABLE II.
Radii of Atoms.

Elements	Viscosity (Rankine)	Compressibility (Richards)	Atomic Structure (Lande)	X-ray Data Davey	X-ray Data Bragg
Fluorine.................	1.17			1.13	.67
Chlorine.................	1.43	1.4	1.6	1.56	1.05
Bromine.................	1.59	1.5	1.8	1.73	1.19
Iodine...................	1.75	1.7	2.0	1.98	1.40
Sodium..................	1.17	1.5	1.1	1.25	1.77
Potassium...............	1.43	1.7	1.45	1.56	2.07
Rubidium...............	1.59	1.9	1.65	1.73	2.25
Cæsium.................	1.75	1.9	1.60	1.98.	2.37

closely as possible.   Bragg's values for the alkali and halogen atoms are given in Table 2, together with a set of values recently published by W. P. Davey, which will be discussed later.

The agreement between the values in the first four columns in

FIG. 17.
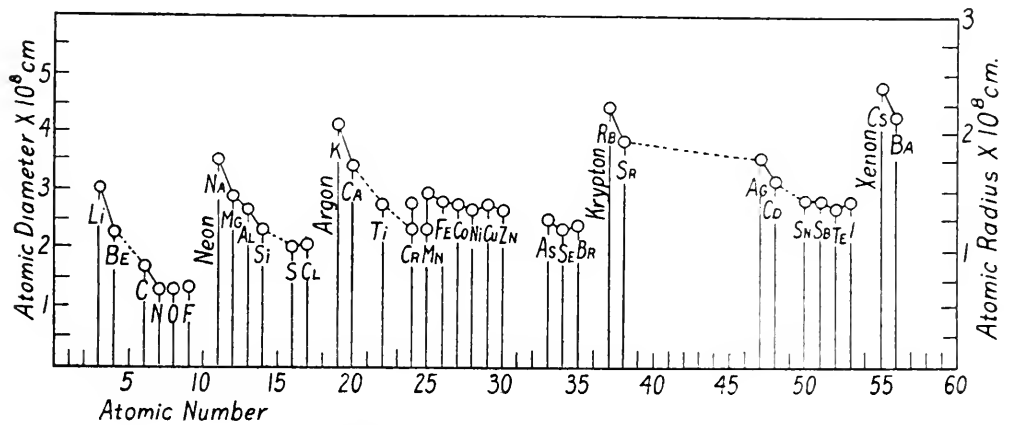
W. L. Bragg's atomic diameters.

Table 2 is remarkable, when one considers the widely different methods by which they were obtained.   Bragg's values, in the fifth column, should not properly be compared with the others, as they were derived for use in building up crystal models *where the negative elements share electrons with each other* and are thus

able to approach much closer, *i.e.*, have smaller apparent diameters.

The Bragg values were included in the table in order to call attention to the fact, emphasized by both Richards and Bragg, that

TABLE III.

Atomic Diameters Determined from X-ray Crystal Analysis. (*W. L. Bragg.*)

Atomic Number	Element	Atomic Diameter in A	Atomic Radius in A
3	Lithium	3.00	1.50
4	Beryllium	2.30	1.15
6	Carbon	1.54	0.77
7	Nitrogen	1.30	0.65
8	Oxygen	1.30	0.65
9	Fluorine	1.35	0.67
11	Sodium	3.55	1.77
12	Magnesium	2.85	1.42
13	Aluminium	2.70	1.35
14	Silicon	2.35	1.17
16	Sulphur	2.05	1.02
17	Chlorine	2.10	1.05
19	Potassium	4.15	2.07
20	Calcium	3.40	1.70
22	Titanium	2.80	1.40
24	Chromium	2.80	1.40
	("electronegative")	2.35	1.17
25	Manganese	2.95	1.47
	("electronegative")	2.35	1.17
26	Iron	2.80	1.40
27	Cobalt	2.75	1.37
28	Nickel	2.70	1.35
29	Copper	2.75	1.37
30	Zinc	2.65	1.32
33	Arsenic	2.52	1.26
34	Selenium	2.35	1.17
35	Bromine	2.38	1.19
37	Rubidium	4.50	2.25
38	Strontium	3.90	1.95
47	Silver	3.55	1.77
48	Cadmium	3.20	1.60
50	Tin	2.80	1.40
51	Antimony	2.80	1.40
52	Tellurium	2.65	1.33
53	Iodine	2.80	1.40
55	Cæsium	4.75	2.37
56	Barium	4.20	2.10
81	Thallium	4.50	2.25
82	Lead	3.80	1.90
83	Bismuth	2.96	1.48

the closeness of approach of atoms depends on the force pulling them together. The apparent diameter will therefore be progressively smaller according as the atoms unite as simple elements,

univalent ions, divalent ions, trivalent ions, or covalence compounds, sharing electrons. An excellent example is calcium,[25] whose atoms have the same face-centered cubic arrangement in the metal, oxide (CaO), and fluoride (CaF$_2$). The oxygen and fluorine ions are able to fit in between the calcium atoms without disturbing their arrangement. Instead of forcing the Ca atoms apart, however, they draw them closer together, the distance between nearest Ca atoms in metallic calcium, CaF$_2$ and CaO respectively being 3.93, 3.88 and 3.42 angstroms. The singly charged fluorine ions are more effective than the free electrons in drawing the Ca atoms together, and the doubly charged oxygen ions still more effective. The difference between the apparent

FIG. 18.

Comparison of Bragg's atomic diameters (circles) with those given in Table I (crosses) and Davey's ion diameters (black dots).
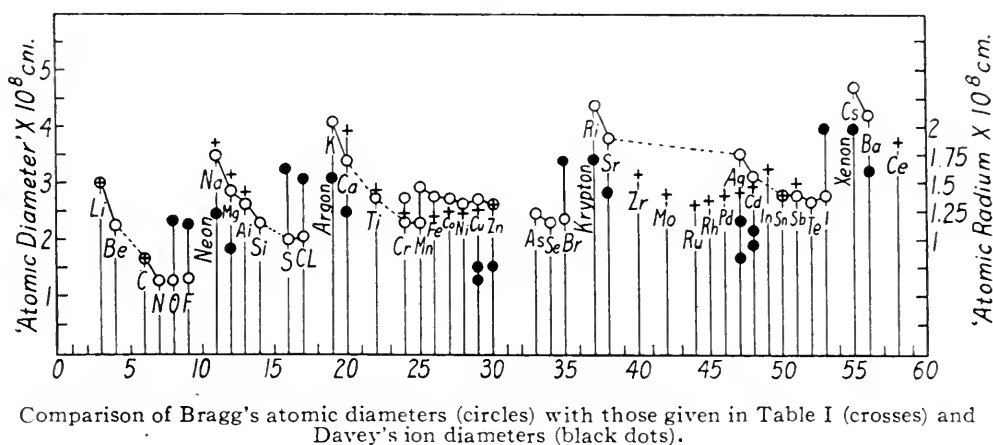
diameter of sodium in the metallic state and in sodium fluoride is still more marked, though in this case the arrangement of the sodium atoms is different in the two cases.

It is probable that when the forces between atoms are better known this variation in apparent diameter can be taken account of in terms of one or more elastic constants, and a definite diameter found for each atom. For the present, however, consistent results will be obtained by using in each particular case that value of diameter which was determined from a compound of the same type as the one under investigation. This has been done by W. L. Bragg, and has proved of great service in the analysis of complex crystals. Bragg's values of atomic diameter are given in Table 3, and shown graphically in Fig. 17. They are based pri-

[25] Hull, *Phys. Rev.*, **17**, 42, 1921.

Table IV.
Crystal Structure of Compounds.

Compound.	Type of Lattice.	Lattice Constant [Side of Elementary Cube, Hexagon, or Rhombohedron.]	Closest Approach of Atoms.		Authority.
			Name of Atom or Ion.	Distance in Angstrom.	
LiF..........	Simple cubic	4.14	Li-F	2.07	Debye [20]
NH₄Cl at 20°C	Body-centered cubic	3.859	NH₄-Cl	3.342	Bragg [21] Bartlett [22]
NH₄Cl at 250°C	Simple cubic	6.533	NH₄-Cl	3.266	Bartlett [22]
NH₄Br at 20°C	Body-centered cubic	3.988	NH₄-Br	3.453	Bartlett [22]
NH₄Br at 250°C	Simple cubic	6.90	NH₄-Br	3.45	Bartlett [22]
NH₄I at 20°C	Simple cubic	7.20	NH₄-I	3.60	Vegard [23] Bartlett [22]
NaNO₃	Rhombohedral	6.06			Bragg [25] Wyckoff [26]
NaF..........	Simple cubic	4.62	Na-F	2.31	Hull [24]
NaCl........	Simple cubic	5.628	Na-Cl	2.814	Bragg [25]
NaBr........	Simple cubic	5.98	Na-Br	2.99	Davey [28]
NaI..........	Simple cubic	6.44	Na-I	3.22	Davey [28]
MgAl₂O₄.....	Diamond cubic				W. H. Bragg [25] Nishikawa [30]
MgO........	Simple cubic	4.22	Mg-O	2.11	Hull [24]
SiC.........	Diamond cubic (nearly)	4.356	Si-C	1.88	Burdick [31]
KF..........	Simple cubic	5.38	K-F	2.66	Hull [24]
KCl.........	Simple cubic	6.30	K-Cl	3.15	Bragg [27]
KBr.........	Simple cubic	6.60	K-Br	3.30	Bragg [27]
KI...........	Simple cubic	7.02	K-I	3.51	Davey [28]
CaCO₃(calcite)...	Rhombohedral	6.16	Ca-C Ca-O C-O	3.04 2.30 1.21	Bragg [25] Wyckoff [32]
CaO.........	Simple cubic	4.84	Ca-O	2.42	Davey [33]
CaF₂.........	Tetrahedral cubic	5.49	Ca-F	2.38	Bragg [25]
CaS.........	Simple cubic	5.64	Ca-S	2.82	Davey [34]
TiO₂ (Anatase) .	Diamond tetragonal	5.27	Ti-O	1.95	Vegard [32]
MnCO₃........	Rhombohedral	5.62	Mn-C Mn-O C-O	2.83 1.96 1.22	Wyckoff [32]
MnS₂.........	....	....	....	......	Bragg [25]
FeCO₃........	Same structure and distance as MnCO₃	....	....	......	Wyckoff [32]
Fe₃O₄.........	Diamond cubic	8.36	....		Bragg [29] Nishikawa [30]
FeS₂.........	Diamond cubic	5.38	Fe-S	2.25	Bragg [25]
NiO..........	Simple cubic	4.15	Ni-O	2.07	Davey [34]
Cu₂O.........	Tetrahedral cubic	4.26	Cu-O	1.84	Bragg [27] Davey [34]
CuCl.........	Diamond cubic	5.36	Cu-Cl	2.32	Wyckoff [36]
CuBr.........	Diamond cubic	5.74	Cu-Br	2.49	Wyckoff [36]
CuI..........	Diamond cubic	6.07	Cu-I	2.63	Wyckoff [36]
CuFeS₂........	Diamond cubic (nearly)	5.23			Burdick [39]
ZnO..........	Tetrahedral hexagonal	3.22	Zn-O	1.97	Bragg [37]
ZnS..........	Diamond cubic	5.41	Zn-S	2.35	Bragg [25]
RbBr.........	Simple cubic	6.92	RbBr	3.46	Davey [28]
RbI..........	Simple cubic	7.32	RbI	3.66	Davey [28]
SrF₂.........	Tetrahedral cubic	5.77	Sr-F	2.50	Davey [34]
Ag₂O.........	Tetrahedral cubic	4.70	Ag-O	2.03	Davey [34]
AgCl.........	Simple cubic	5.56	Ag-Cl	2.78	Wilsey [38]
AgBr.........	Simple cubic	5.78	Ag-Br	2.89	Wilsey [38]
AgI..........	Diamond cubic	6.53	Ag-I	2.83	Wilsey [38]
CdO..........	Simple cubic	4.61	Cd-O	2.30	Davey [33]
CdS..........	Tetrahedral hexagonal	4.16	Cd-S	2.54	Davey [34]
SnS..........	Tetrahedral hexagonal	3.60	Sn-S	2.20	Davey [34]
CsCl.........	Body-centered cubic	4.10	Cs-Cl	3.55	Davey [41]
CsBr.........	Body-centered cubic	4.33	Cs-Br	3.75	Davey [41]
CsI..........	Body-centered cubic	4.57	Cs-I	3.96	Davey [28]
CsCl₂........	Rhombohedral				Wyckoff [40]
BaF₂.........	Tetrahedral cubic	6.20	Ba-F	2.69	Davey [34]
BaS..........	Simple cubic	6.40	Ba-S	3.20	Davey [34]
TlCl.........	Body-centered cubic	3.85	Tl-Cl	3.34	Davey [41]
PbS..........	Simple cubic	5.80	Pb-S	2.90	Davey [34]

marily on compounds in which the electronegative elements share electrons.

Another set of diameters, based entirely on monovalent and divalent ions, has recently been published by Davey.[26] Davey postulates the approximate equality of the K^+ and Cl^- ions in KCl, Rb^+ and Br^- ions in RbBr, and Cs^+ and I^- ions in CsI. Other monovalent ions are then found by differences. For the sake of comparison Davey's values and the values for pure elements, from Table 1, are shown on the same plot with Bragg's values in Fig. 18.

Finally, a list of the compounds that have been analyzed, arranged in order of atomic weight of the metal, is given in Table 4. The lattices referred to are the complete lattices of *ions*, counting both kinds; for example, by simple cubic lattice is meant a lattice like Fig. 16, in which half the positions are filled by positive ions and half by negative. The body-centered cubic lattice is like Fig. 12, the diamond cubic lattice like Fig. 13. The rhombohedral lattices are similar to Fig. 16, but stretched or shortened in the direction of one of the cube diagonals.

REFERENCES FOR TABLES 1 AND 4

[1] Hull, *Phys. Rev.*, **10**, 661, 1917.
[2] W. H. and W. L. Bragg, *Proc. Roy. Soc. A.*, **89**, 277.
[3] Debye and Sherrer, *Physik. Z.*, **18**, 291, 1917.
[4] P. Sherrer, *Physik. Z.*, **19**, 23, 1918.
[5] Debye and Sherrer, *Physik. Z.*, **17**, 277, 1916.
[6] Hull, *Phys. Rev.*, **17**, 42, 1921.
[7] Hull, *Phys. Rev.*, **18**, 88, 1921.
[8] Hull (unpublished).
[9] Hull, *Phys. Rev.*, **17**, 571, 1921.
[10] A. Westgren, *Z. f. physik. Chem.*, **98**, 182, 1921.
[11] Bohlin, *Ann. d. Physik.*, **61**, 421, 1920.
[12] W. L. Bragg, *Phil. Mag.*, **28**, 355, 1914.
[13] Vegard, *Phil. Mag.*, **31**, 86, 1916.
[14] Bijl and Kolkmeijer, *Proc. Roy. Akad. Amsterdam*, **21**, 501, 1919.
[15] James and Tunstall, *Phil. Mag.*, **40**, 233, 1920.
[16] P. Debye, *Physik. Z.*, **18**, 483, 1917.
[17] Vegard, *Phil. Mag.*, **32**, 65, 1916.
[18] James, *Phil. Mag.*, **40**, 233, 1920.
[19] Bain, *Chem. Met. Eng.*, **25**, 657, 1921.
[20] Debye and Sherrer, *Physik. Z.*, **19**, 474, 1918.
[21] W. H. and W. L. Bragg, "X-rays and Crystal Structure," p. 158.
[22] Bartlett and Langmuir, *J. Am. Chem. Soc.*, **43**, 85, 1921.
[23] Vegard, *Phil. Mag.*, **33**, 395, 1917.
[24] Hull, *Proc. A. I. E. E.*, **38**, 227, 1919.
[25] W. L. Bragg, *Proc. Roy. Soc. A.*, **89**, 468, 1914.
[26] Wyckoff, *Phys. Rev.*, **16**, 149, 1920.

[26] W. P. Davey, *Phys. Rev.*, **18**, 102, 1921; *Am. Phys. Soc.*, Nov., 1921.

[27] W. H. and W. L. Bragg, "X-rays and Crystal Structure," p. 91.
[28] W. P. Davey, *Phys. Rev.*, 18, 102, 1921.
[29] W. H. Bragg, *Phil. Mag*, 30, 305, 1915.
[30] S. Nishikawa, *Tokio Sug. But. Kizi*, 8, 199, 1915.
[31] C. L. Burdick and E. A. Owen, *J. Am. Chem. Soc.*, 40, 1749, 1918.
[32] R. W. G. Wyckoff, *Am. J. Sci.*, 50, 317, 1920.
[33] W. P. Davey, *Phys. Rev.*, 15, 333, May, 1920.
[34] W. P. Davey, *Am. Phys. Soc.*, Nov., 1921.
[35] L. Vegard, *Phil. Mag.*, 32, 505, 1916.
[36] R. W. G. Wyckoff, *J. Am. Chem. Soc.*
[37] W. L. Bragg, *Phil. Mag.*, 39, 647, 1920.
[38] R. B. Wilsey, *Phil. Mag.*, 42, 262, 1921.
[39] Burdick and Ellis, *J. Am. Chem. Soc.*, 39, 2518, 1917.
[40] Wyckoff, *J. Am. Chem. Soc.*, 42, 1100, 1920.
[41] Davey and Wick, *Phys. Rev.*, 17, 403, 1921.

On Phosphorescent Zinc Sulphide. R. TOMASCEK. (*Ann. d. Phys.*, No. 11, 1921.)—Much labor of investigation has been expended on the study of the phosphorescence of commercial zinc sulphide, but owing to ignorance of the exact chemical composition of the material employed all too much of this work has gone for nothing.

Chemically pure zinc sulphide was prepared with care. This showed after it had been illuminated either no phosphorescent light or so little as to be almost invisible. As the material approached chemical purity, the phosphorescent light accordingly became less and less, just as has been found to be the case with the phosphorescing compounds of the alkali earths. When a heavy metal was introduced into such a mass of zinc sulphate it became phosphorescent. For example, .000006 gram copper per gram of the sulphide produced a splendidly glowing substance. The method of crystallization of the compound seems to have no influence on the result.

The effect of the addition of small quantities not only of copper and manganese, whose efficacy in producing phosphorescence has long been recognized, but as well of Bi, Ag, Pb, Ur, Ni and Co was investigated. The preparations made with these six elements were in general not so brilliant as the copper and the manganese complexes are at ordinary temperatures, yet most of them when illuminated at the temperature of liquid air and then heated display fine and characteristic phosphorescent light. The addition of a trace of nickel caused an intense color to appear at room temperature.

With certain metals four circumstances of the admixture were examined as to their influence on the light of phosphorescence, *viz.*, the proportion of metal added, the temperature at which this trace was heated with the zinc sulphide, the duration of this heating and the flux employed.

This investigation will go far toward disentangling the twisted threads of experimental results that have so long with baffling confusion annoyed and misled in this field.

G. F. S.

FOGS AND CLOUDS.*

BY

W. J. HUMPHREYS, C.E., PH.D.

Professor of Meteorological Physics, United States Weather Bureau,
Department of Agriculture, Washington, D. C.
Associate Editor, Member of the Institute.

EVAPORATION AND PRECIPITATION.

WHERE FROM AND WHERE TO.

EVERYONE knows that rain and snow come out of the clouds, and that every cloud and fog particle is either a water droplet or an ice crystal. Naturally, therefore, one asks where all this endless supply of water comes from; endless, because year after year, century after century, and age after age, rain and snow have descended as they now descend. And where, too, does it all go, this world average of sixteen million tons a second? The answers are: It comes from the soil and its vegetation, from rivers, lakes and the oceans; and to them it returns—an endless cycle of evaporation and condensation.

> "The mist and cloud will turn to rain,
> The rain to mist and cloud again."
> —*Longfellow.*

EVAPORATION.

The first of these processes, namely, evaporation, consists in the change of water (water in this case, though many substances behave similarly) from the liquid, or even solid, state to that of an invisible gas, in which condition it becomes an important, though always relatively small, part of the air we breathe.

The rate of this evaporation depends on a number of things, the more important of which are:

a. The area of the evaporating surface. The larger the surface the more rapid the total evaporation. It is in recognition of this law that we spread out a drop or even a puddle of water to hasten its disappearance.

b. The temperature of the evaporating water. The higher

---

* Based on a lecture given before the Section of Physics and Chemistry of The Franklin Institute on January 5, 1922.

this temperature the more rapid the evaporation. That is why heating things hastens their drying.

c. The velocity of the wind to which the water is exposed. This explains why roads, for instance, dry so much quicker when the winds are strong than when they are light.

d. The amount of moisture already in the atmosphere. The wash on the clothes-line, as every housewife knows, dries provokingly slowly during cloudy, muggy weather.

All the other factors that affect the rate of evaporation, such as density of the air, saltiness of the water, *et cetera,* generally are small in comparison with the above, and need not here be considered since it is only intended to make perfectly clear, through our everyday experiences, the wide occurrence and great importance of evaporation.

SATURATION.

Although evaporation, as just stated, is so very general there are conditions under which things will not dry, nor bodies of water any longer decrease. Thus even a rather small amount of water in a tightly closed bottle, or other impervious vessel, remains there indefinitely. The space above the water becomes saturated, we say, by which we mean that it gets so charged with water vapor that, under the existing conditions, it can contain no more. At this stage the net evaporation is zero. That is, the amount of the invisible water vapor that now goes back, or condenses, into the liquid stage is exactly equal to that which, in the same time, leaves the liquid surface and becomes invisible vapor. In other words, at this stage, however rapid the interchange between liquid and vapor, the amount of each remains constant.

Numerous careful experiments have determined very closely the exact weight of water vapor per cubic foot, say, when the space in question is saturated at any given temperature, from the boiling point to far below that of freezing. And these experiments show two facts of paramount importance in the formation and dissipation of clouds, namely:

1. The amount of moisture necessary to produce saturation increases rapidly with increase of temperature.

2. The amount of water vapor essential to saturation is not appreciably affected by the presence or absence of the other gases of the normal atmosphere.

It is true that even in technical language we often say that the *air* contains such or such an amount of moisture, as though the presence of the air was essential to the existence of the vapor, or as though the air acted somehow like a sponge in taking up water. But, as explained, this idea is wholly wrong. The only appreciable effect of the presence of the other gases of the atmosphere on the moisture is that of slowing the rate of its spread or diffusion. Temperature and temperature alone, to within a negligible amount, determines the quantity of vapor per any given volume necessary to produce saturation, or, of course, any definite percentage or fraction of saturation.

CONDENSATION.

The percentage of saturation produced by a given amount of water vapor may, therefore, as is obvious from the above discussion, be varied by altering the volume it occupies or its temperature, or both; and as rapidly as saturation tends to be exceeded moisture condenses out onto any water surface or solid that may be present. Thus, the deposition of dew, the formation of hoar-frost, and the sweating of ice pitchers, all are examples of condensation owing to passing the saturation point, or dew-point, as it commonly is called. In these cases just mentioned the temperature of the water vapor, and, of course, of the other constituents of the atmosphere, which, however, play no part in the condensation, is lowered through contact with cold objects, and the volume of this vapor as well as that of the accompanying chilled gases, decreased—decreased because in the open air the pressure remains constant, or nearly so, whatever the degree of cooling.

Similarly, whenever the temperature of the open air passes below the dew-point condensation occurs in the form of innumerable water droplets or tiny ice crystals throughout the chilled volume, and thereby produces a fog or a cloud, as determined by location—a fog if on the surface, a cloud if only in mid-air.

The natural processes by which a given body of the atmosphere may be sufficiently cooled to lose a portion of its water vapor by condensation are: (1) Contact with objects colder than itself; (2) mixing with colder air; (3) radiation; (4) expansion.

Condensation as a result of contact cooling is well illustrated, as already explained, by the deposition of dew—the bedewed

objects having been cooled by radiation; by the formation of hoar-
frost, which occurs under the same conditions, except at a lower
temperature, as does dew; and by the sweating, during warm
humid weather, of all cold objects. It is further illustrated by the
formation of fog, generally light, when relatively warm humid
air drifts over a snow bank or other cold surface.

The second of the above processes of inducing condensation,
that is, the mixing of masses of humid air of different temperatures,
is not very effective. Indeed an accurate calculation, based on the
temperature and volume changes and other factors of the problem,
shows that while a fog or cloud may be obtained by this process
no appreciable amount of rain or snow is likely to result. Layer
or stratus clouds at the boundary between relatively warm air above
and cold beneath, a phenomenon of occasional occurrence, are at
least partially due to mixing, as are also the fogs that so frequently
occur over adjacent warm and cold ocean currents.

The third process by which air loses heat, namely, by radiation,
probably is of little importance in the production of clouds since
the most chilled portions of free air sink to lower levels and
thereby become even warmer and drier than they were at first.
Near the surface, however, where descent and the consequent
dynamical warming, as it is called, are impossible, radiation often
is very effective in the production of fog.

The last of the cooling processes mentioned above, that is, ex-
pansion, is exceedingly effective, and to it is due the great bulk of
cloud formation. Now, expansion of the air may be produced either
by heating it or by reducing the pressure to which it is subjected.
It is the latter process, obviously, and not the former, even though
heating generally is the initial cause, that produces the cooling of
free air and the formation of cloud. To make these points clear,
consider the results when a given mass of humid air is heated,
as it may be, over a region warmed by sunshine or otherwise.
With increase of temperature it expands and thereby becomes
lighter, volume for volume, than the surrounding cooler air. The
surrounding denser air then underruns the lighter and lifts it up
to higher levels just as hot air is driven up a chimney. As the
warmed air is thus forced up (rises, as we generally say)
the pressure to which it is subjected obviously decreases in pro-
portion to the weight of the air left below. It therefore gradually
expands as it rises and thereby does work, and since the only

energy available for this work is the heat of the ascending air it follows that as its height increases its temperature must correspondingly decrease. As a matter of fact, for air of average humidity, the rate of this decrease is approximately 1° F. per 187 feet increase of elevation up to the base of the cloud, if there be one, in the rising air, and then much less through the cloud. In any event the ascending air attains equilibrium only when it has cooled by expansion to the temperature of the air that finally surrounds it. Hence when it comes to rest it is colder, often much colder, than it was before it was heated.

Of course the expansion of the rising air correspondingly increases the vapor capacity, but it is easy to show, both theoretically and experimentally, that this increase of vapor capacity by volume expansion is small in comparison with its simultaneous decrease through the lowering of the temperature, and that convectional expansion therefore, whether incident to the blowing of wind up and over mountains, or to local heating, is a most effective means of inducing condensation and the formation of clouds.

CONDENSATION NUCLEI.

Whenever ordinary air, kept humid by the presence of water, is suddenly expanded in a closed vessel, it instantly becomes filled throughout with a miniature cloud, precisely as occurs on an incomparably larger scale in nature. Subsequent expansions of the same air, otherwise undisturbed, induce less and less cloud and presently none at all. If filtered air, that is, air drawn through several inches of cotton wool, or other substances of similar texture, is used, condensation by moderate expansion is impossible from the first. The admission, however, of a little smoke restores to the exhausted air, and endows the filtered air with, full powers of condensation. There are, therefore, condensation nuclei in the atmosphere—hundreds and often thousands of them per cubic inch—which can be filtered out; and microscopic examination shows that they consist essentially of dust particles. Hence, dust, moisture and some cooling process are the three essential factors in all natural fog and cloud formation.

It is true that a few substances other than dust, such as the oxides of nitrogen, act as condensation nuclei, but they seem generally to be negligible in quantity. Furthermore, condensation can be obtained in air wholly free from any such nuclei provided it

is ionized and forced to at least a fourfold supersaturation, a degree of humidity that probably never occurs in nature. Indeed under very great supersaturation, eight- or ninefold, condensation occurs even in perfectly clean non-ionized air. But this, too, is only a laboratory experiment, and not a process by which clouds are formed in nature.

FOGS.

DISTINCTION BETWEEN FOG AND CLOUD.

As already explained, whenever the air is cooled, by any means whatever, below its dew-point, a portion of the water vapor present separates out on such dust particles or other condensation nuclei as may happen to be present. If this process occurs only at a considerable distance above the surface of the earth, leaving the lower air clear, the result is some form of cloud. If, on the other hand, it extends quite to, or occurs at, the surface of the earth it is then called a fog no matter how shallow nor how deep it may be. The distinction, therefore, between fog and cloud is that of position. Fog is a cloud on the earth; cloud, a fog in the sky.

In some cases the only basis of distinction between fog and cloud is that of viewpoint. For example, the mist that sometimes covers only the crest of a mountain generally is called fog by those actually in it, and cloud, at the same time, by those in the valley below.

WHERE AND HOW FORMED.

Fogs are likely to form along rivers and large creeks and in the mountain valleys of all but arid regions in the latter part of any still cloudless night of summer or autumn. During these seasons the streams and the humid soil are warm, especially when exposed to sunshine, and hence evaporate much moisture into the lower atmosphere, where, in great measure, it remains when there are no winds to blow it away.

Throughout the night, however, the surface of the soil and the adjacent humid air, by virtue of its humidity, lose heat rapidly by radiation to the colder atmosphere above and to the sky, or empty space, beyond. This loss of heat by radiation is no greater, of course, by night than in the daytime, but when there is no sunshine to make good such loss, or do better—as generally is the case through the forenoon—the inevitable consequence is a lowering of

the temperature. Hence, during calm, clear nights the temperature of the humid surface air often falls below the dew-point and a fog of corresponding depth and density is formed.

If the sky is overcast there commonly is enough radiation from the clouds back to the earth, especially if they happen to be low (hence warm), to prevent the cooling of the surface air to the dew-point and the consequent formation of fog. Neither does fog form when there is considerable wind, partly because the more humid lower air is then mixed with the drier upper air and the surface dew-point thereby lowered, and partly because this mixing prevents much fall in the surface temperature by distributing the loss of heat through a relatively large amount of air instead of leaving it confined essentially to that near the ground. Hence fogs of the kind under consideration—radiation fogs, summer fogs, land fogs, valley fogs—seldom occur either when the sky is cloudy or the night windy.

Another source of numerous fogs is the drifting of relatively warm humid air over places much colder, such as the drifting of on-shore winds over snow-banks. In this way the humid air frequently is cooled below its dew-point and fog—" winter fog " or " sea fog "—produced. Likewise, heavy fogs often are formed when the wind is from warm to cold water—from the Gulf Stream to the Labrador Current, for instance.

Fogs also frequently occur when cold air slowly flows in over warm water. This explains the " frost smokes " of polar seas, and the " steaming " of rivers and lakes on cold frosty mornings. In these cases the relatively warm water goes on evaporating into the cold air even after it becomes saturated and thereby produces a water droplet or a minute ice crystal about every one of the myriad millions of nuclei present. If, however, the cold air comes in with a rush, that is, if it enters as a strong wind, no fog is produced, simply because the vapor is distributed by the accompanying turbulence through too large a volume to produce saturation.

KINDS.

In respect to the ways in which they are formed, fogs may be divided into two classes :

1. *Radiation fog* (Fig. 66, *Physics of the Air* [1]), due to the cooling of the lower air below the dew-point, partly by its own

---

[1] Book published by The Franklin Institute. 1920.

radiation and partly by contact with the surface which itself had cooled by radiation. This type of fog is common, as already

Fig. 1.

Advection fog, seen from Mount Wilson, Cal. (F. Ellerman, photo.)

explained, along streams and in valleys where, through the summer and autumn, it is apt to occur on any calm, clear night.

2. *Advection fog* (Figs. 1, 2), produced by the advection, or horizontal movement of air from one place to another, such as the drifting of relatively mild air from the ocean inland over snow-

banks, or from a warm current to a cold one; and the flow of frosty air over open water. Furthermore, any fog, when shifted to a new position may then be called advection fog. Usually, too, the

FIG. 2.

Advection fog, seen from Mount Wilson, Cal.   (F. Ellerman, photo.)

shifted fog, like that so common on many leeward coasts, is advective also in origin.

There also are several other classifications of fogs, less scientific perhaps, but often very convenient. Thus we speak of

dry fog, meaning a fog which, because of the small amount of water content, does not wet our clothing—evaporates as fast as caught up—or else meaning, as we often do, a haze caused by a forest fire, dust storm, or volcanic explosion; *wet fog,* meaning one containing so much water that, like a Scotch mist, it makes at least the surface of one's clothing distinctly damp; *sea fog,* fog originating on the ocean, whether remaining there or drifting on shore; *land fog,* one occurring in the country and which, as its nuclei are but slightly hygroscopic, quickly evaporates; *city fog,* one occurring over a city, especially a city that uses a large amount of soft coal and has but few smoke consumers, generally slow to evaporate, owing jointly, presumably, to the hygroscopic nature of the nuclei and to the oil in the unburned sooty smoke; *black fog,* one containing a great amount of soot, such as occasionally forms over large, smoky cities; *pea-soup fog,* a local name given to those London fogs that contain only a moderate amount of smoke particles—just enough to give the fog a distinctly yellowish cast; *ice fog,* or "frost smoke," the fog of polar seas, caused by the drifting over them of very cold air; and many others, mostly of less interest and of small importance.

QUANTITY OF WATER CONTAINED.

It might seem, on first thought, that it would be a very easy thing to measure the amount of liquid water in a given volume of fog, but this amount is so small that even tolerably accurate measurements of it require much care. Nevertheless, it has been reliably measured. Thus, in the course of an official Ice Patrol cruise in the *Seneca* about the southern edge of the Grand Banks of Newfoundland, that is, in the region of one of the most frequented of the steamer lanes, Wells and Thuras measured the water content of a dense fog that occurred on the evening of May 9, 1915. In this fog there were about 20,000 droplets per cubic inch. In their report they say: "To gain some idea of the order of magnitude of the quantities involved in this dense fog, assume that one can not see beyond 100 feet. A block of fog 3 feet wide, 6 feet high and 100 feet long contains less than one-seventh of a glass of liquid water. This water is distributed among 60 billion drops."

Barely one good swallow!

SIZE AND NUMBER OF PARTICLES.

The size of fog particles is easily and accurately determined by looking through the fog at a point (pin-hole) source of bright light and noting the difference in direction toward centre and circumference of any definite one of the rings of colored light seen around this source—rings of precisely the same nature as the coronæ produced by thin clouds around the sun and moon. This angular size, or difference in direction between centre and circumference of any one of these rings, increases as the diameter of the fog particles decreases, and in such known and definite manner that when either is given the other can at once be accurately calculated.

If, then, we know the size of the fog particle and if, in addition, we know the amount of liquid water in a given volume of fog, which, as explained above, can be measured, it obviously is only a matter of easy arithmetic to find the number of such particles per cubic inch, say, or any other given volume.

The numbers, however, so obtained are surprising. Everyone knows, of course, that a fog droplet is small, but not many, perhaps, realize that 2500 of them, of the average size, placed side by side in a single row would extend only one inch, or, in other words, that it would take half an hour to count a string of them an inch long!

Nor is the number of fog particles in a definite volume any less amazing. It is but a light fog that has only 1000 droplets per cubic inch; a heavy fog has around 20,000. Indeed, vastly greater numbers have often been found, even up to nearly a million per cubic inch.

But these droplets, as explained, are so excessively minute that the very maximum density of a million per cubic inch would still leave the empty space 4000 times greater than the volume actually occupied by all the liquid present.

IMPRESSIONS.

If one would thrill his soul with beauty let him, on a brilliant, moonlit night, view from the mountain's crest a far flung fog over all the piedmont region beyond, with foothills and knolls rising here and there as so many enchanted islands in an enchanted sea. Let him, as the dawn breaks clear, gaze from a mountain top on an incipient, fibrous fog, covering a neighboring valley with a fabric more gauzy and delicate than ever Arachne spun. Let him

stand on the topmost peak of rugged Tamalpais and watch in wonder the mighty fog billows crowd through the Golden Gate, break over the barrier mountain crests, and rush down their sides in an all engulfing flood. Let him view from afar the snow-crowned crest of incomparable Fuji, floating without visible support, in a clean, clear sky while all its base and the region around is lost in deep fog and delicate mist.

These are but some, and typical, of the most beautiful and fascinating of fog effects; so impressive, indeed, that we could not forget them if we would, and so charming that certainly we would not forget them if we could.

But the impressions produced by fog are not always so charming and entrancing. If one would go quite to the opposite extreme and experience its terrors let him get lost in London's darkest and densest fog. Let him be alone at night in an unfamiliar forest and have settle down upon him so thick a fog that literally he can not see his hand before him. Let him, on the ocean in the dead of night, between the shrieks of his own ship's siren hear from somewhere, just somewhere, within the encircling gloom, the same dread warning. Let him, when flying over strange territory, be forced to land in a deep, dense fog!

All these, and many others, are horrors one longs to forget, but can not.

And so it is that, from extreme to extreme, from fascination to fear, from delights we fondly cherish to dreads we would fain forget, fog in all its moods and circumstances plays compellingly upon the whole gamut of human emotions.

CLOUD FORMS.

It is passing strange that the ancient Arabs, Greeks and others should have given a name to every portion of the heavens, and to numerous individual stars—names still in current use throughout the civilized world—and yet have failed to name any one of the many kinds of clouds that are even more conspicuous in the sky than the stars themselves or their constellations. Perhaps giving them names long seemed both useless and impracticable owing to their infinite variety and ceaseless changes, for indeed, as Shakespeare puts it:

Sometimes we see a cloud that's dragonish,
A vapour sometimes like a bear or lion,
A towered citadel, a pendent rock,
A forked mountain, a blue promontory
With trees upon't that nod unto the world
And mock our eyes with air.
That which is now a horse, even with a thought,
The rack dislimns and makes it indistinct
As water is in water.

But whatever the cause, there was not, down the ages, until the very modern year 1801, any attempt whatever to classify the clouds, although from the beginning everybody everywhere talked about the weather and many wrote about it. This first attempt, made in 1801, as just stated, was by the French naturalist, Lamarck. It received little attention, however, and no general acceptance; owing in part, presumably, to the fact that it was expressed in the words and phrases of a distinctly local or national language unfamiliar to the world at large.

But the time for a practical classification of the clouds was ripe. The need for it was felt by the large number of educated and cultured people who were then taking an active and inquisitive interest in the weather and its ways. Hence in a little while another classification was proposed, this time, 1803, by the Englishman, Luke Howard. Like that of Lamarck's it too was based on the *appearance* of the clouds, but the names, instead of being only locally understood, were all in tolerably familiar Latin —the Esperanto of the day. At any rate, whether this universal language had much to do with it or not, Howard's classification soon became well known and extensively used; so much so indeed that all subsequent practical classifications have been but extensions of this original one published in 1803, with the addition, perhaps, of a few unusual and, commonly, unimportant types. some of which Howard probably never saw.

To obtain uniformity in the cloud reports of professional meteorologists, and of all others who wished to be clearly understood, the International Meteorological Committee published in 1910, with illustrations, the following definitions and descriptions of cloud forms. The enclosed letters next after each type name are its customary abbreviation. The illustrations are new (the original ones are not available) but quite as good and typical, it is hoped, as those selected by the committee.

The wording here followed of these international definitions and descriptions is not exactly that of the original publication, but that given in the second edition of " Cloud Forms," 1921, by the British Meteorological Office.

This latest classification of the clouds, a modification and extension of Howard's, is also, like it, based on mere *appearance* and not on anything really fundamental, such as cause or mode of formation. But however superficial such a classification may be it nevertheless is the best, perhaps, that can be made, and altogether the most practical. For instance, the mode of origin is not a practical basis for cloud classification, however desirable, because several types of cloud are formed in different ways and frequently one cannot be certain just what the actual way really was.

The supplementary remarks, after each of the following quoted definitions and descriptions, while intrusive in position, may, it is hoped, be of some service to those who are not yet cloud experts.

<center>(To be continued)</center>

Lost Lake in Nevada. (*U. S. Geological Survey Press Bulletin No. 481.*)—During comparatively recent geologic time a great lake flooded a number of the valleys in northwestern Nevada. This lake has now almost completely disappeared, but geologists have named it, in its entirety, Lake Lahontan, in honor of Baron La Hontan, one of the early explorers of the headwaters of the Mississippi. At the time of its greatest expansion, according to the Geological Survey, this ancient lake covered 8400 square miles. The deepest part of Lake Lahontan, which was 880 feet deep, was the site of the present Pyramid Lake, one of its remnants, so that its surface stood about 500 feet above the surface of Pyramid Lake. The ancient lake had no outlet except the one that led straight up, its waters being dissipated entirely by evaporation.

A large area a few miles north of Winnemucca, Nevada, is covered with sand dunes that were formed since Lake Lahontan disappeared. These dunes are fully 75 feet thick, and their steeper slopes are on the east side, indicating that the whole vast field of sand is slowly traveling eastward. The march of this sand is irresistible, and its progress has necessitated a number of changes in the roads in the southern part of Little Humboldt Valley during recent years. In some places in this region the telegraph poles have been buried so deep that they have had to be spliced in order to keep the wires above the crests of the sand dunes. The sand is of a light creamy-yellow color and forms beautifully curved ridges and waves that are covered with an artistic fretwork of wind ripples.

THE EFFECT OF THE FORM AND DIMENSIONS OF THE SAMPLE UPON THE ACCURACY OF X-RAY CRYSTAL ANALYSIS BY THE POWDER METHOD.*

BY

L. W. McKEEHAN, Ph.D.

Research Physicist, Engineering Department, Western Electric Company.

An X-ray crystal analysis of certain alloys by the powder method [1] has shown that errors due to the finite dimensions of the samples employed become appreciable when maximum accuracy is attempted. Since the effect of varying the proportion of the metals forming an alloy, or of varying its properties by any other means, is usually to change slightly the dimensions of the crystal lattice, without changing its kind, the estimation of the magnitude of such errors, and efforts to reduce them, seemed worth while.

The apparatus available was designed and constructed by the staff of the Research Laboratory of the General Electric Company, and permits simultaneous analysis of as many as fifteen samples. The spatial relations of the parts essential for the analysis of one sample are indicated in Fig. 1, which is a projection on the (vertical) plane through the centre, M, of the molybdenum target from which the X-rays diverge, the centre, N, of the (horizontal) cylindrical sample, and the centre-line, ST, of the photographic film which is bent over a cylindrical frame coaxical with the sample. The diameter of the sample and the thickness of the cylindrical tube necessary for non-coherent powders or materials which are modified by exposure to the atmosphere, have, for convenience in reference, been enormously exaggerated. Points in Fig. 1 which are projections of points lying outside the plane of projection are primed. When attention is to be called to the position of these points in space the primes will be suppressed.

The fundamental equation of the method is

$$n\lambda = 2d \sin \theta$$

---

[1] For a complete description of the method see papers by A. W. Hull, *Phys. Rev..* (2), **9**, 84-87. 1917; **10**, 661-696, 1917.

wherein λ is the wave-length of the X-rays, n is an integer termed the " order of reflection," θ is half of the observed deviation of the days, and d is the perpendicular distance between the consecutive planes in the crystal from which reflection takes place. The radiation is filtered so that λ can for a first approximation be regarded as a constant. On this assumption only a limited number of values of d and n which satisfy the condition

$$\frac{d}{n} \not< \frac{\lambda}{2}$$

can give real reflections. Let the admissible values of $\frac{d}{n}$ be desig-

Fig. 1.
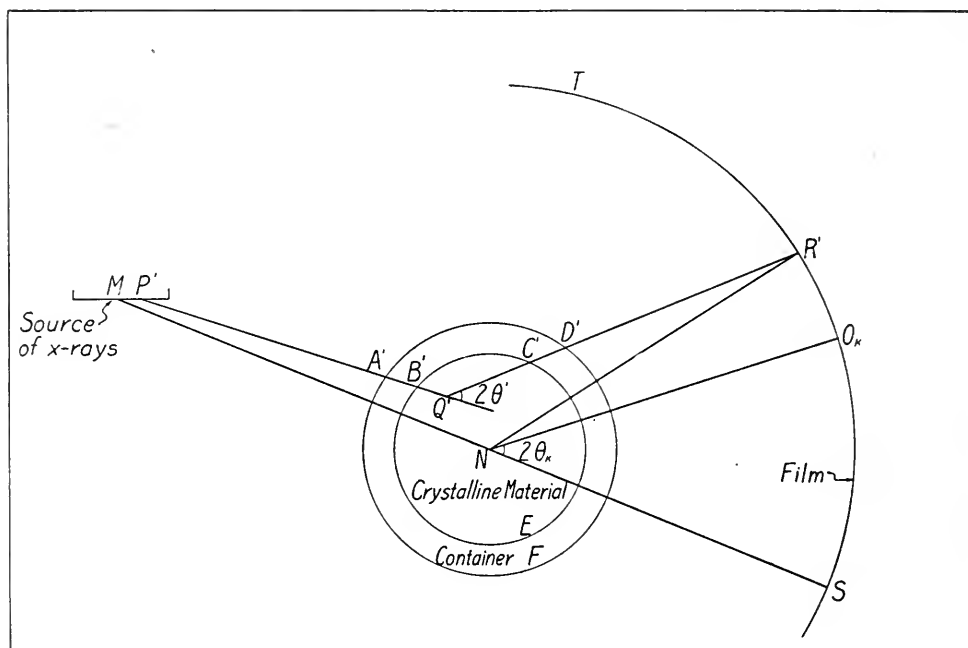
nated $d_1, d_2, d_3, \ldots d_k \ldots d_m$, in order of decreasing magnitude, and the corresponding values of θ be designated $\theta_1, \theta_2, \theta_3, \ldots \theta_k, \ldots \theta_m$, in order of ascending magnitude. The data will furnish some, rarely all, of the possible values of θ_k, and the corresponding values of d_k determine the kind and dimensions of the crystal space lattice.

The accurate determination of θ_k, or more strictly of $2\theta_k$, the angle of deviation, is the problem to be solved. The measurement is reducible to that of a single length, SO_k, on the centre-line of the film after it has been exposed, developed, fixed, washed and dried. All the other lengths involved in the calculation of $2\theta_k$ are constants characteristic of the film-box and sample-holder. If

the film guides are not true circles centered on the axis of the sample, the length of SO_k as measured must be suitably corrected, the correction being a function of SO_k alone, before θ_k and d_k are computed.

The filters, which render the X-rays monochromatic to an extent sufficient for photography, are placed in the incident beam close to the X-ray tube, and in the diffracted beams close to the film. They are not indicated in Fig. 1. The effect of heterogeneity in the radiation reaching the film will be discussed later; meanwhile it will be assumed that only a single wave-length is present.

The focal spot on the target is of finite dimensions, but for the first approximation it can be assumed that all the X-rays diverge from the centre of the focal spot. The slits which limit the incident beam are of such dimensions and so placed that at the sample the cross-section of the beam which is of full intensity is a rectangle 1.8 cm. horizontally by 0.15 cm. vertically. It will be assumed that the X-ray tube, slit system, and sample-holder are correctly arranged so that the central portion of the sample lies entirely within this rectangle.

The film [2] is 40.4 cm. by 4.7 cm. and as limited by guides, screens and filters the undeviated X-rays form upon it a rectangular spot about 4 cm. by 0.5 cm., 8 cm. from the lower end. The deviated rays form a strip of diffuse blackening about 3 cm. wide, beginning about 2 cm. above the undeviated spot and extending with diminishing intensity for about 25 cm. along the centre-line of the film. This strip, due to scattering by amorphous material, stray and unfiltered radiation, is crossed by darker bands which cut the centre-line of the film very close to the points O_1, O_2, ... O_k, ... O_m, whose positions are desired. The sample casts its shadow on the undeviated spot as a lighter band, the centre-line of which cuts the centre-line of the film at the point S.

The shadow of the sample must be clear enough so that the point S can be located at least as accurately as the points O_k. This requires that the absorption in the sample be appreciable, since any attempt to locate S by an auxiliary exposure using an opaque object in place of the sample largely increases the accidental errors affecting the measurement of SO_k.

The blackening of the film at any point R, in excess of that due to the diffuse radiation mentioned above, is due to diffraction from

---

[2] Eastman Portrait Film $1\frac{7}{8}'' \times 16''$.

every crystal in the sample which can deviate rays through any angle so as to fall at the point R. The intensity of X-radiation of wave-length λ incident from a point P of the source upon an element, at Q, of a properly exposed sample, depends only upon the intensity on a plane perpendicular to PQ at unit distance from P, upon the length of PQ, and upon the absorption in intervening matter. The absorption in the wall of the X-ray tube, in the filter, and in the air is the same for all points of the source and of the sample. The absorption in the sample itself and its container depends principally upon the position of Q and only very slightly upon the position of P. If the arrangement of crystals in the sample is truly chaotic, as desired, the same fraction of the total mass in every element of volume is in position to deviate some incident radiation through the angle 2θ where θ has any assigned value. Of course, if θ is not nearly equal to θ_k, one of the values corresponding to the crystals forming the sample, the fraction so deviated will be negligible, but this can more conveniently be taken account of at a later stage in the analysis, so that at present θ will be regarded as unrestricted.

The distribution of the radiation deviated through 2θ in the element of volume at Q is symmetrical about PQ as an axis, the deviated rays thus forming a thin conical shell with apex at Q. The point R is a point on the intersection of this cone with the film. The component normal to the film at R of this deviated radiation from Q is proportional to the whole intensity deviated through 2θ at Q and depends also upon θ, upon the length QR, upon the absorption in matter between Q and R, and upon the angle QR makes with the normal to the film at R. The absorption in the sample itself and in its container is again seen to be the only absorption which varies much with the choice of Q.

Holding the point R fixed and permitting P and Q to take all possible positions consistent with the boundary conditions at the source and sample we can now write down the expression for the total intensity of radiation received normally at R,

$$ I_R = A_R + \int_P ds \int_Q u(P,Q) w(\theta_{P,Q}) \left\{ \frac{I}{PQ^2} \cdot \frac{I}{QR^2} \cos(QR \cdot NR') \right. $$
$$ \left. e^{-\mu_E(BQ+QC) - \mu_F(AB+CD)} \right\} dv $$

wherein A_R is the intensity of diffuse radiation. The volume

integral is to be taken throughout the sample, the surface integral is to be extended over the source. The absorption has been assumed to be exponential, μ_E and $\mu_F{}'$, referring to the sample and its container, respectively. The function $u(P,Q)$ contains all the factors dependent upon the position of P and the direction of PQ with respect to the axis of the X-ray tube. The function $w(\theta_{P,Q})$ includes all the factors which depend on the position of Q only through the corresponding value of θ. Its value has maxima at or near [3] $\theta = \theta_k$, and is practically zero elsewhere.

The resolution of the bands in the photograph is complete at R if only one maximum in w is included within the range in θ permitted by the possible positions of P and Q. This cannot, unfortunately, always be the case unless the unit of crystal structure is small, for the dimensions of the sample, and particularly its length, cannot be reduced without great loss of intensity, and adjacent values of θ_k often lie very close together.

The relative dimensions of the apparatus are such that several approximations can be introduced without serious error, provided R is kept near O_k which includes all the interesting portion of the photograph. We may put

$$u(P,Q) = u(P,N) \quad,$$

$$\int_P u(P,N)\,ds = G \quad, \quad \text{a constant}$$

$$\frac{I}{PQ^2} \cdot \frac{I}{QR^2} = \frac{I}{MN^2} \cdot \frac{I}{NO_k{}^2} = C_k, \quad \text{a constant}$$

$$\cos(QR \cdot NR') = I \quad,$$

$$\frac{A_R}{I_R} = 0 \quad,$$

$$B'Q' = BQ \;, \quad Q'C' = QC \;, \quad A'B' = AB \;, \quad C'D' = CD \;,$$

$$w(\theta_{P,Q}) = w_k \quad \text{for } \theta_k + \epsilon > \theta > \theta_k - \epsilon,$$

$$w(\theta_{P,Q}) = 0 \quad \text{for } \theta > \theta_k + \epsilon \text{ and } \theta_k - \epsilon > \theta,$$

leaving

$$I_R = G\,C_k\,w_k \int_{\theta_k - \epsilon}^{\theta_k + \epsilon} \left\{ e^{-\mu_E(B'Q' + Q'C') - \mu_F(A'B' + C'D')} \right\} dv$$

---

[*] Wilson, H. A., *Phys. Rev.*, (2), **18**, 396-401, November, 1921.

wherein the limits for the integration include all the points, Q, of the sample from which a sensible intensity is deviable to R by the given crystalline material. In the above simplified expressions ϵ is a small angle, 2ϵ being the width of the rectangle which best fits the peak in the w, θ, curve, and w_k being its altitude, so that

$$2\,w_k\,\epsilon = \int_{\theta_k - \delta}^{\theta_k + \delta} w\,(\theta)\,d\theta$$

FIG. 2.
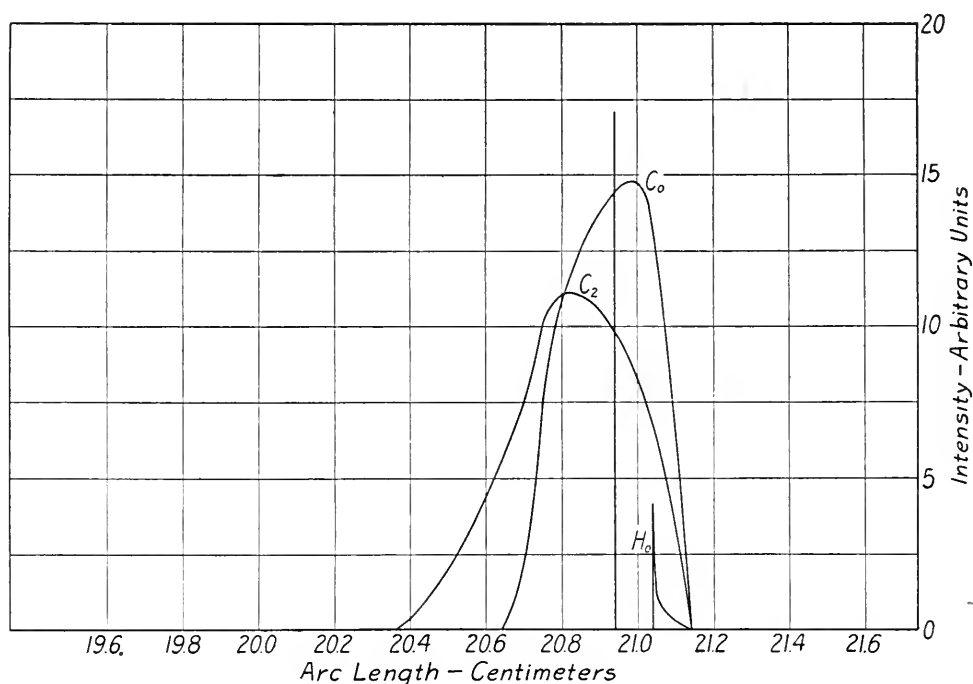
wherein δ is any angle large compared with ϵ but small compared with $\theta_{k+1} - \theta_k$ and $\theta_k - \theta_{k-1}$.

In the case to be treated herein the value of ϵ is entirely negligible with respect to the angles subtended by the bands on the photograph, so the volume integration can be replaced by integration over the surface produced by rotating the arc PQR about its chord PR. The last equation takes the form

$$I_R = G\,C_k\,W_k \int_{\theta_k} \left\{ e^{-\mu_E\,(B'Q' + Q'C')} - \mu_F\,(A'B' + C'D') \right\} ds$$

Even with these simplifications a formal solution has not been obtained, but enough special cases have been approximately computed to indicate the type of variation to be expected if the blackening of the photograph is approximately proportional to I_R, as it is in the case of under-exposure usually occurring. The remaining figures show the results of computation in several cases, the curves being lettered to correspond to the nomenclature given in the table below. The subscript of the letter placed close to each curve gives the distance in centimeters from the centre-line of the film to the line for which the intensity is plotted (e.g., A_0 refers to the centre-line, A_2 to a parallel line two centimeters away). A vertical line on each figure represents the point to which measurement should be made, the point O_k in the preceding analysis.

TABLE I.

Principal Dimensions:
Source to sample	MN = 20 cm.
Sample to film	NS = 20 cm.
Length of sample	2 cm.
Thickness of container	0.025 cm.

Coefficient of absorption in container μ_F = 10 cm. $^{-1}$

SAMPLE

Case	$2\theta_k$	Diam.	μ_E	Mass (Relative)	Container
A	60°	0.20	10	50	no
B	60°	0.20	10	50	yes
C	60°	0.20	3	160	no
D	60°	0.20	3	160	yes
E	60°	0.40	5	100	no
F	28°	0.20	10	50	no
G	60°	*0.01	10	1	no
H	60°	0.20	∞	—	no

*Thickness of plate.

A study of the results permits the following conclusions to be drawn:

(a) The breadth and the dissymmetry of the band increase as the distance from the centre-line of the film increases, even in the most favorable case, C, (Fig. 2). The changes are the more rapid the smaller the value of θ_k (Figs. 7 and 8).

(b) The container has little effect in displacing the lines, as appears by comparing cases A and B (Figs. 3 and 4) or C and D (Figs. 5 and 6).

(c) If the sample is relatively opaque it may be very advantageous to dilute it with amorphous material of negligible

absorption coefficient, the dimensions of the sample being unchanged. The gain due to smaller absorption may far outweigh

Fig. 3.

Arc Length — Centimeters

Fig. 4.

Arc Length — Centimeters
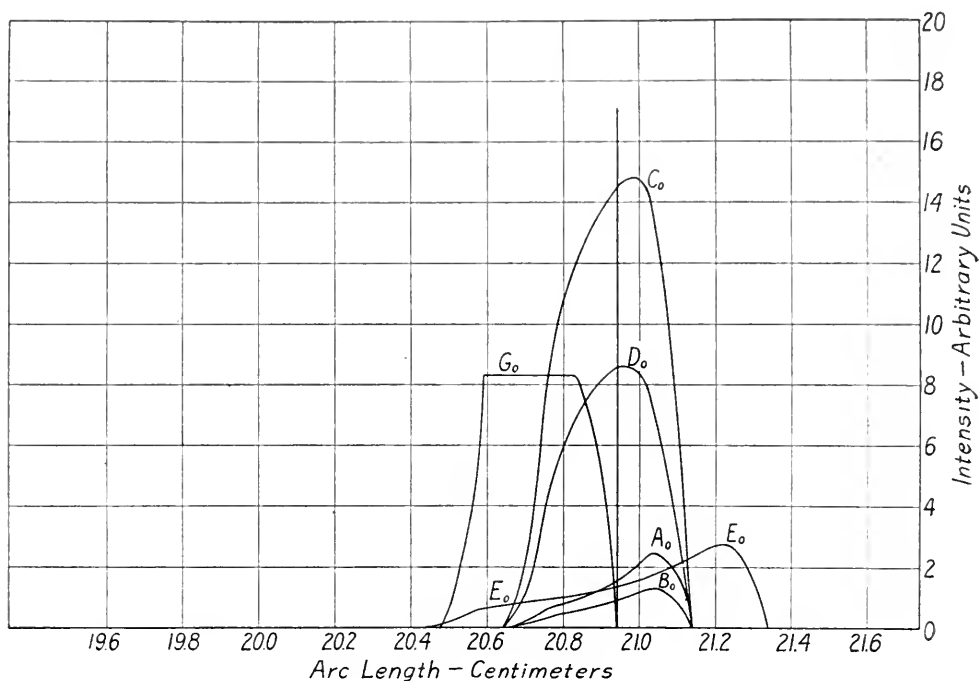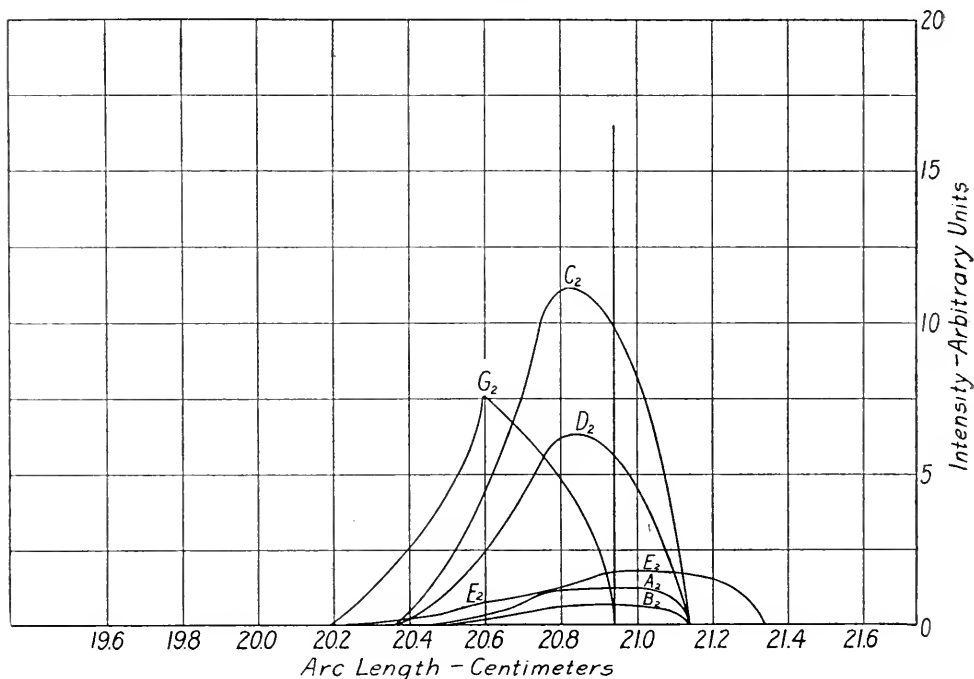
the loss due to smaller mass of crystalline material. This is illustrated by cases A and C, or B and D (Figs. 3 and 4).

(*d*) It is clear without special proof that the errors in position

of the apparent centres of the bands are nearly proportional to the
diameter of the sample.   As an example of this compare cases *A*

FIG. 5.
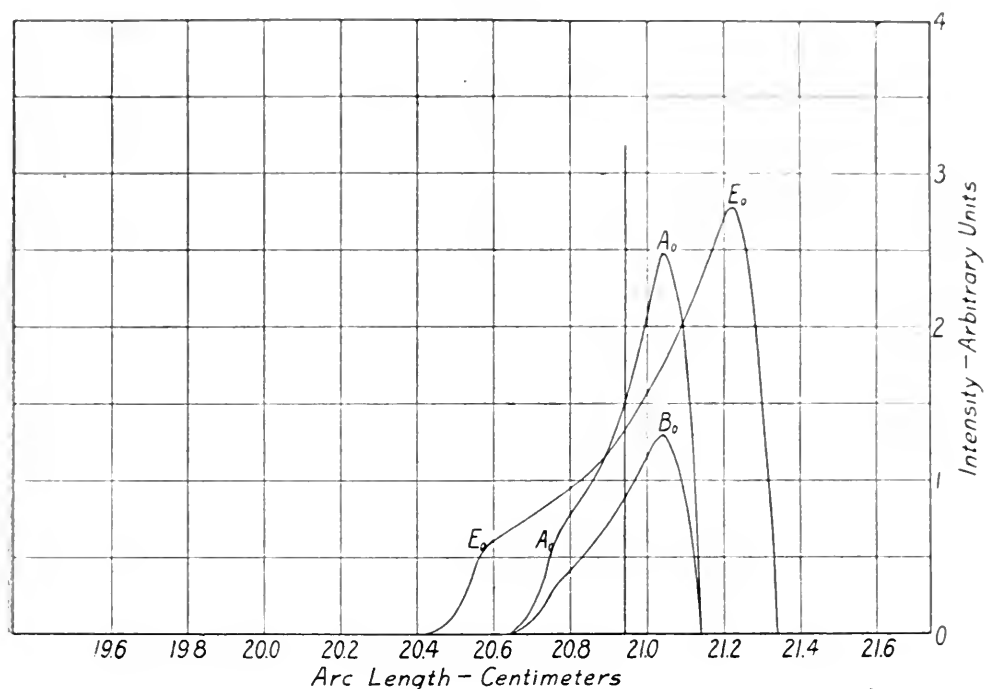
FIG. 6.
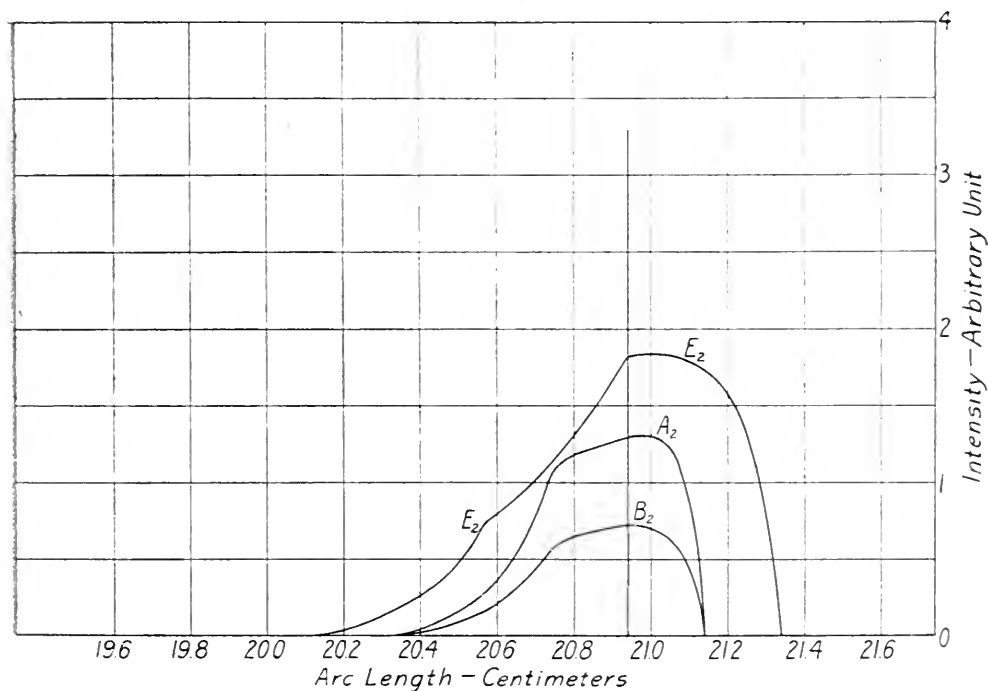
and *E* (Figs. 5 and 6). It is always an advantage to reduce exces-
sive opacity by reducing the diameter of a sample rather than by

diluting it, provided the manipulative difficulties do not become too great.

(e) The smaller the value of θ_k the greater is the width of the band and the more dissymmetrical it is. Whether the error in estimating its position is greater or less depends upon other factors. Compare cases A and F (Figs. 7 and 8). It should be noted that equal percentage accuracy requires greater absolute accuracy the smaller the value of θ_k.

Fig. 7.

Arc Length — Centimeters
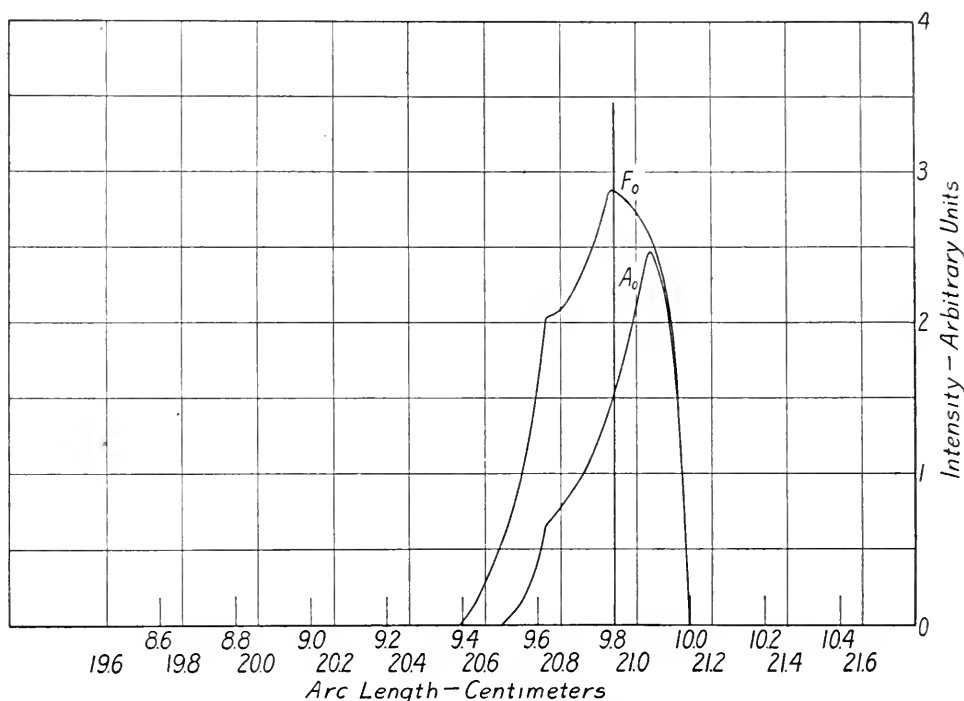
Most of the metals of technical importance have such high absorption coefficients that cylindrical samples of suitable diameter for accurate photographs are so small that very long exposures would be necessary. It was found easier to obtain intense photographs by modifying the shape of the sample, replacing a thin circular cylinder by a thin ribbon with one edge along the axis of the film. Calculations similar to those carried out for cylindrical samples give intensities shown in the table and curves as case G (Figs. 3 and 4). The point to which measurement must be made in this case is the limit of the band, which is relatively easy to locate even when the photograph is rather faint. The presence of a region of uniform intensity close to this limit makes its location easier than in the previous case. The central spot is also cut more

sharply, permitting additional accuracy in measurement. Neither of these advantages can be gained by shifting the axis of a cylindrical sample and making measurements up to the limits of the bands. Attention is particularly invited to the small mass of material which is necessary for a relatively intense photograph. For the heavier metals particularly, this method of mounting has great advantages. If the grains are too large it is possible to combine this advantage with that obtained by rotating samples of

FIG. 8.

Arc Length — Centimeters
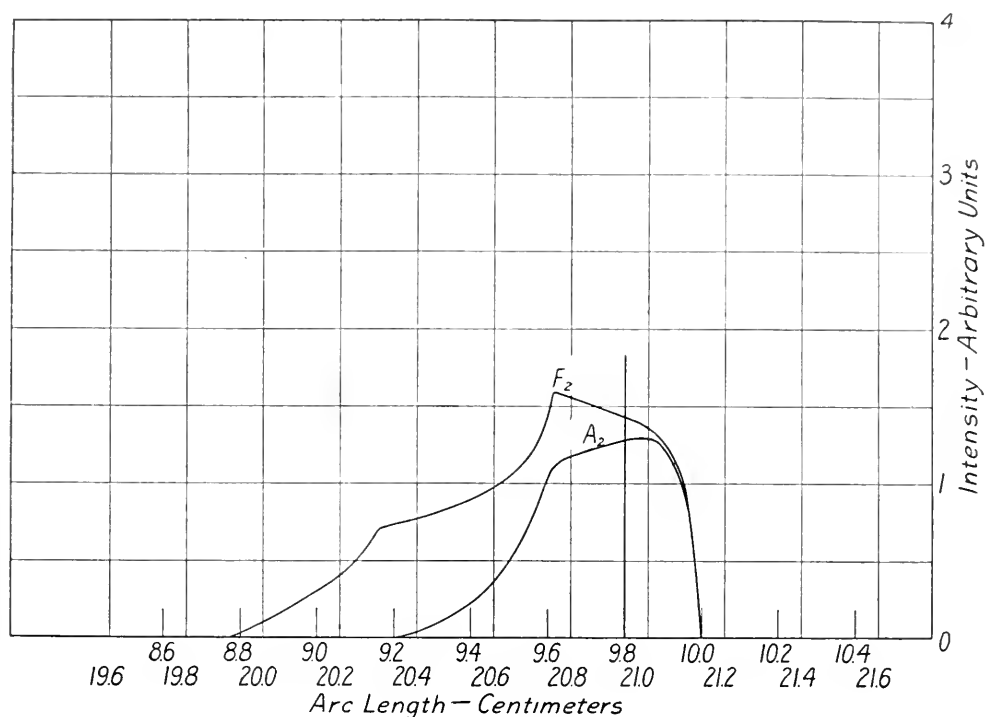
the more usual form, by rocking the plate about its edge through any angle less than $2\theta_m$.

If the opacity of a cylindrical sample is very great indeed the surface elements contribute practically all the intensity photographed and act as does the edge of the thin plate. The observed position of the band requires, however, a correction to be made for the variable position the effective surface elements assume as θ changes. The necessity for this correction has been pointed out by Bijl and Kolkmeijer [4] in their work on the crystalline structures of tin, wherein relatively large rods were used. The limiting case of infinite absorption has been computed as case H (Fig. 2). This case is mentioned by recent investigators as occurring in the case

---

[4] Bijl, A. J., Kolkmeijer, N. H., *Proc. Amst. Acad.*, **21**, 494-500, 1919.

of magnesium oxide for copper characteristic X-rays [5]. The shape of the curve is excellent for accurate measurement, but the intensity (not to scale in Fig. 2) is vanishingly small.

If the X-rays reaching the photographic film are not monochromatic a complete pattern of bands will be produced by each wave-length present in sufficient intensity. The principal difficulty arises in the actual apparatus, from the fact that both components of the K_α doublet are present in sufficient intensity to affect the film. Since the wave-lengths are 0.712Å and 0.708Å the corresponding parts of the two patterns are 0.10 cm. apart at about 17 cm. from the undeviated spot. When the crystals are sufficiently small resolution of the smooth bands is more difficult and has only occasionally been observed in the best photographs. The extreme edge should always correspond to the lower wave-length, 0.712Å, and this is accordingly to be used in computing the values of d_k when the doublet is not resolved. When large crystals are present in the sample, irregular variations in the intensity within the bands due to a single wave-length are observed, and the larger crystals give lenticular spots [6] clearly resolvable in the case of K_α doublet, and separated by the expected intervals at all distances greater than 6 cm. from the undeviated spot.

The presence of these discrete spots due to the larger grains affords a ready means of observing the early stages in grain growth, and does not materially affect the accuracy with which a value of θ_k can be found until the crystals are so large that they begin to reflect other wave-lengths than those of the K_α doublet and until their number is too few to justify the postulate of random distribution in position and orientation.

CONCLUSION.

Both theory and experiment indicate that, when great accuracy is desirable in the analysis of highly absorbent crystals, a thin plate is preferable to a circular cylinder. If a cylindrical form is unavoidable, the smallest diameter which gives a measurable photograph will be found to be the best.

[5] Gerlach, W., Pauli, O., ZS. f. Physik., 7, 116-123, Oct. 21, 1921.
[6] Bijl, A. J., Kolkmeijer, N. H., Proc. Amst. Acad., 21, 407, 1919.

NOTES FROM THE U. S. BUREAU OF STANDARDS.*

ANNUAL REPORT OF THE DIRECTOR, BUREAU OF STANDARDS, 1921.[1]

[ABSTRACT.]

In conformity with the general policy of the Government in restricting expenditures wherever possible without serious detriment to the public service, the Bureau of Standards has, during the fiscal year ended June 30, 1921, confined its activities to the more urgent research problems and testing. This has necessarily meant a curtailment in various directions, but it is believed that from the point of view of value received for money expended the year covered by the last annual report of the Director of the Bureau to the Secretary of Commerce has been a notable one.

Close coöperation with the industries and other Government departments, both National and State, has been continued with satisfactory results. The number of tests completed during the year was 67,398 for the Government and 26,638 for the public, a total of 94,036 tests of all sorts. It should be remembered that this work has been carried out with smaller expenditures and a reduced personnel.

During the year the staff of the Bureau has been composed on an average of 342 statutory employees and 508 engaged in special research work authorized by Congress. This is a total of 850 as compared with 981, the average for last year. However, there has been a decided improvement in turn-over of the personnel and the more stable conditions existing during the fiscal year now under consideration have improved the quality of the research work.

Important progress was made during the year in the recomparison of the Bureau's fundamental standards of measurement, and the condition of these is steadily improving.

The Annual Conference on Weights and Measures held on May 23–26 was largely attended; several important questions were considered, including the sale of bread by weight, specifications and tolerances for liquid measuring devices, and the methods of weighing coal.

---

* Communicated by the Director.
[1] Miscellaneous Publications No. 47.

New specifications for incandescent lamps purchased by the Government were prepared during the year by the Bureau, as the old specifications, written a number of years ago and several times revised, were out of date. A total of 2,750,000 lamps were ordered by the Government during the year, all these orders stipulating that the lamps should conform to the specifications of the Bureau. These specifications are typical of many issued during the year, not only by the Bureau, but by many other organizations with which the Bureau coöperated, covering all classes of materials.

Important work has been done in ways and means for conserving our supply of natural gas, in some of this work the Bureau having the coöperation of the Bureau of Mines.

A thorough investigation of the strength of fire resistance of various types of building construction has been pushed vigorously throughout the year, and the important investigational work on airplane and automobile gasoline engines has been continued.

A spectroscopic method of analyzing gold and other precious metals was successfully developed and turned over to the Treasury Department for their use.

The coöperative research work with the Bureau of Engraving and Printing in the development of a satisfactory electrolytic printing plate has been continued and the process has been in regular use by that Bureau during the year.

Important progress has been made in several metallurgical lines, such as the car-wheel investigation mentioned last year. The work on cement gypsum, and other building materials has also been pushed, but it has been necessary to discontinue a portion of the cement inspection work at the mills.

Optical glass of satisfactory quality has been supplied to the Navy Department, and valuable experience is being gained in the manufacture of this important material.

Research work covering a period of many years will soon have culminated in the preparation of tables on the physical constants of ammonia. This is the most thorough work of the kind ever carried out.

The results of the Bureau's work are made available to the public through its publications, of which 86 were issued during the year. Twenty-four reprints of previous publications and a supplement to the list of publications were also issued. A new series of " Hand-books " has been started and will be made up of weights

and measures manuals, safety codes, etc. Many articles have appeared in scientific and technical journals, written by members of the Bureau's staff, and service has also been rendered through representation on committees, consultation with visitors, and by means of correspondence.

The Technical New Bulletin, describing current investigations, has been issued each month in mimeograph form as heretofore.

INFLUENCE OF PHOSPHORUS UPON THE MICRO-STRUCTURE AND HARDNESS OF LOW-CARBON OPEN HEARTH STEELS.[2]

By Edward C. Groesbeck.

[ABSTRACT.]

Since there appears to be scanty information of a systematic nature in the published literature with regard to the influence of varying amounts of phosphorus, especially within the limits usually found in open hearth and Bessemer steel of commercial grades, upon the microstructure and physical properties of low-carbon steel as developed by heat-treatment, this investigation was undertaken with the object of throwing additional light upon the rôle played by phosphorus upon the properties of low-carbon open hearth steels, which are often used in the manufacture of products where severe cold-working is employed during fabrication. Because of the very limited amount of material made available for this investigation, the scope of work was confined to the study of microstructure and hardness, as developed by a series of seven heat-treatments, in specimens cut from 1-inch rounds that had been fabricated from two series of low-carbon steel ingots, one of basic open hearth steel and the other of acid open hearth steel, which Dr. J. S. Unger had prepared several years ago in connection with his investigation into the effect of varying phosphorus-content upon the endurance qualities of low-carbon open hearth steel when severely cold worked. Both series of steels had the general chemical composition: 0.12 per cent. carbon, 0.36 per cent. manganese, 0.022 per cent. silicon, 0.037 per cent. sulphur, and 0.014 per cent. copper, while the phosphorus-content varied within the limits 0.008 to 0.115 per cent.

The series of heat-treatments given the specimens, which were

---

[2] Technologic Papers. No. 203.

in the shape of a quadrant of ½-inch radius and were ¼-inch thick, consisted of heating the specimens in an electric tube furnace to 900° C., followed by cooling down through the 900° to 600° C. range in the following periods of time: 8 hours, 4 hours, 2 hours, 1 hour, 30 minutes and 10 minutes. In addition, one set of specimens was heated in a lead bath to 900° C. and allowed to cool with the bath down to 500° C. when the specimens were taken out and air-cooled.

A study of the micrographs taken of all the heat-treated specimens at near each corner of the quadrant-shaped specimens showed that there was a marked irregularity in the distribution and size of both the ferrite and pearlite grains in many of the specimens, especially in the acid open steel series, and that there was no definite relation between the occurrence of this irregularity of structure and the phosphorus-content and heat-treatment.

Because of the irregularity in structure, no clearly defined relationship could be established between the phosphorus-content and the grain-size, as determined by the Jeffries method, and also the Shore scleroscope hardness, though a small but definite increase in Brinell hardness could be traced as the phosphorus-content was raised.

This irregularity in structure is evinced in many cases by the presence of large carbonless or pearlite-free areas and abnormally large ferrite grains, was shown by metallographic etching to be due to the non-uniform distribution of the phosphorus, there being a greater concentraton of this element within these areas than in the surrounding metal.

A cellular-like structure formed in conjunction with the microstructure normal to these steels was studied and relationship between this unusual structure and the distribution of the phosphorus was established. This cellular-like structure, as developed by etching with an alcoholic solution of nitric or picric acid, comprised of a light-colored network of cell-wall system with darker-colored meshes, and appeared to be independent of and superposed on the usual ferrite and pearlite system. It was found present in the steels containing at least 0.03 per cent. phosphorus, and was more pronounced as the phosphorus-content increased, which fact was further established by the study of a number of specimens of a medium carbon steel, containing 0.42 per cent. phosphorus, that had been heated to 800° and 900° C. and cooled down through the

800-650° range at various rates. Proof of this relationship between the cellular-like structure and the distribution of phosphorus was given by the etching patterns as developed by etching with Stead's reagent. These etching patterns corresponded exactly in position with and overlapped the cellular-like structure previously developed by picric or nitric acid, and were also more pronounced in the higher phosphorus steels than in the lower phosphorus steels.

CUTTING FLUIDS. [3]

By Eugene C. Bingham.

[ABSTRACT.]

PART I. THEORY.

Machinists have long recognized lard oil as being well-nigh indispensable in certain cutting operations, whereas for the majority of operations in the machine shop much cheaper oils may be used to advantage. The reasons for the superiority of lard oil have not been clearly understood, but they turn out to be closely related to the general theory of lubrication, and with the development of fast-moving machines this theory is of vast economic importance.

One function of a cutting fluid is to cool the work, and for this purpose water with its high specific heat is suited. But since water tends to rust the machines, alkaline substances are added such as soda or soap.

In difficult cutting operations, the chip is apt to " seize " the tool, causing dulling of the tool, roughness of the work, *et cet.,* hence it is inferred that in such cases a good lubricant is required and therefore water is out of place.

The experiments of Tower led many to the erroneous belief that two oils of the same viscosity would have the same lubricating value. Consequently the cheaper mineral oils have been regarded as equivalent in every respect to the fatty oils which they once supplanted. There are certain operations in the machine shop such as the threading of micrometer screws, parting of mild steel, threading and tapping wrought iron, boring gun-barrels in which no mineral oil, regardless of its viscosity, will produce the excellent results obtained with lard or other fixed oils. With lard oil, the

---

[3] Technologic Papers, No. 204.

surface obtained is smoother, the chip is less serrated and longer, the tool lasts longer, the production is increased, there is less heating, and the machine runs steadier.

It appears that whenever two *clean* surfaces of metal are brought together they tend to seize. Many examples prove that a quite invisible layer of impurity will prevent seizure. The clean metal of the chip moving over the face of the tool under great pressure affords a peculiarly difficult problem in lubrication. Lard oil has a much higher *adhesion* for metal than do the pure mineral oils. It is drawn in between the chip and the tool and forms a strong film which prevents the chip from adhering to the tool and forming a " bead." Other oils containing fatty acids, or groups of atoms with " residual affinities," such as sperm oil, castor oil, rape oil, *et cet.,* have in large measure the advantage of lard oil.

It seems readily possible to improve mineral oils as cutting fluids and as lubricants by adding liquids of high adhesion such as oleic acid, pine oil and fixed oils. Methods are suggested for the measurement of adhesion. While this paper was in the course of preparation, the Deeley friction testing machine and the Lanchester worm gear machine were being developed in Great Britain, which demonstrate the superiority of the fixed oils as lubricants and the advantage of adding fatty oils or their acids to mineral oils to be used as lubricants.

PART II. PRACTICE.

Correspondence with the large machine shops in America with regard to their practice in the use of cutting fluids elicited information worthy of record.

The purposes of cutting fluids are to cool the work, lubricate, lessen wear, insure a good finish with accurate dimensions, wash away chips, and prevent the formation of dust. The materials used may be classified as (a) oils, (b) air, (c) aqueous solutions and water, and (d) emulsions.

Oils may be animal oils, fish oils, vegetable oils, mineral oils or compound oils. The edible animal oils are too expensive to use as a lubricant, hence only the inferior grades are used for this purpose. Fish oils are objectionable unless deodorized, vegetable oils tend to gum, and mineral oils are low in adhesion and are therefore poor lubricants. Compound oils are largely used, containing a large percentage of mineral oil with a smaller percentage of vegetable or animal oil, or both. Air is used merely to remove chips.

Water alone is used to some extent, but on account of the tendency to rust, soda, sodium silicate, sodium resinate or other soap are usually added.

Emulsions have the advantage of cheapness while possessing much better lubricating properties than the aqueous solutions. They are of three types. Mineral oil compounded with neutralized sulfonated oil will form a permanent emulsion when mixed with various proportions of water. Mineral oils are compounded with an alcoholic solution of soap. A third variant is marketed as a paste, it being a thick soap solution and mineral oil. The second type is the most desirable and the third is the least so.

As to the choice of a cutting fluid for a given operation, the character of the operation performed has more to do with the choice of cutting fluid than the character of the metal. For drilling, reaming, milling, planing and sawing emulsions are generally satisfactory. For tapping and threading and parting off compound oils and lard oil are often resorted to. Compound oils are used with automatic screw-cutting machines.

The material cut is also of importance. There is a general consensus of opinion that soft steel and wrought iron are difficult metals on which to get a good surface without lard or sperm oils. They are called " draggy " metals. Cast iron on the other hand, being brittle, does not adhere to the tool and no lubricant is required. Contrariwise, on a hard, brittle steel, lard oil merely produces a " glaze," and turpentine is used with success.

The formulas of cutting oils used by large and successful users are given.

In the search for the true explanation of the remarkable "oiliness" exhibited by lard oil, the surface tension, specific gravity, and specific heat of several oils were studied by A. W. C. Menzies. The fluidity was studied by W. G. Kleinspehn.

TENSILE PROPERTIES OF SOME STRUCTURAL ALLOY STEELS AT HIGH TEMPERATURES. [4]

By. H. J. French.

[ABSTRACT.]

The report gives results of determination of tensile strength, proportional limits, elongation, reduction of area and strength at

[4] Technologic Papers, No. 205.

fracture throughout the range 20 to 550° C. for four steels containing about 0.38 per cent. carbon, as follows: (a) Plain carbon steel; (b) 3½ per cent. nickel steel; (c) 3 per cent. nickel, 1 per cent. chromium steel, and (d) 1 per cent. chromium, 0.2 per cent. vanadium steel.

Brief reference is made to the type of fractures obtained in testing steels at various temperatures, and particular attention is paid to comparison of the tensile properties of these alloys at 550° C. in the neighborhood of which various parts of converters are subjected to stresses in production of ammonia by the Haber process.

Of the four steels tested in normalized condition it appears that the two alloys containing chromium show greater resistance to weakening by increase in temperature to about 550° C. than either the plain carbon or 3½ per cent. nickel steels, and at this high temperature the chromium-vanadium steel is to be preferred from the standpoint of high tensile strength and limit of proportionality.

The carbon and 3½ per cent. nickel steels behave alike with rise in temperature above that of the room, and at about 550° C. the addition of 3½ per cent. of nickel appears to have little or no effect on the tensile properties of the carbon steel.

Measurements of the Compressibility of Solids. E. Madelung and R. Fuchs. (*Ann. d. Phys.*, No. 12, 1921.)—The solid of about 2 c.c. volume was placed in a glass vessel terminating above in a capillary tube. Below a ground-glass joint permitted the introduction of the solid. The remaining volume of the vessel was occupied by mercury which reached up into the fine tube. When pressure was applied externally to the glass vessel and its contents, changes of volume manifested themselves by changes of level in the mercury contained in the tube.

Pressures are expressed in megabars, that is, in millions of dynes per sq. cm. One megabar equals 1.019 kg. per sq. cm. or .987 atmosphere. The pressures employed in the experiments reached to 148.6 megabars. About 60 substances were tested, most of which were minerals. Of all these corundum made synthetically had the smallest coefficient, *viz.*, .38. This means that the application of a pressure of one megabar reduces the volume of this material by .00000038 of its uncompressed volume. For paraffin the corresponding quantity is .00003336, nearly 90 times as great. The need for accurate determinations of compressibility will appear from the following values found by different experimenters for copper—1.25, Regnault; .87, Amagat; 1.61, Voigt; .90, Madelung and Fuchs.

G. F. S.

NOTES FROM THE LABORATORY OF PURE SCIENCE NELA RESEARCH LABORATORIES.*

BRIGHTNESS OF LIGHT SOURCES.

By W. E. Forsythe.

THE brightness of several different light sources has been measured by different methods and previously reported. The values given in the table include some additional data.

The first method used was to measure the brightness with an optical pyrometer having a yellow-green glass as a monochromatic screen. This pyrometer was calibrated, using a black body as standard, so as to give values in candles per square centimetres. The second method was to measure the brightness through a small opening of known size by means of a regular photometer. The third method used was to measure the color temperature and the brightness, and from these values and the known brightnesses of a black body to calculate the brightness.

The results given in the table were all obtained by the use of at least two of these methods wherever it was possible, and those for the different sources—in particular the white mazda and the frosted lamps—are the average of readings obtained on a number of different lamps. Some results previously published are added for purposes of comparison.

Source	Brightness Candles per cm².
Kerosene flame	1.3
4–watt carbon filament	51.0
0.9–watt tungsten filament	227.0
Same lamp frosted	2.5
50–watt white mazda—outside	1.29
50–watt white mazda filament	408.0
2000–watt mazda—outside coil	864.0
2000–watt white mazda—inside coil	2021.0
Same type lamp frosted—outside	105.0

* Communicated by the Director.

RADIATION EQUILIBRIUM IN AN OPAQUE UNIFORMLY HEATED SOLID AND DUANE'S HYPOTHESIS AS TO ITS ORIGIN.

By A. G. Worthing.

WHETHER or not the *natural radiation* from the ultimate sources of radiation in an opaque uniformly heated solid agrees in spectral distribution with the *equilibrium radiation* in their immediate neighborhood depends on the optical constants of the solid. The condition for agreement is constancy in $\frac{k}{\lambda}$, where k (often written nk) is the extinction coefficient and λ the wave-length in vacuo. A considerable tendency toward constancy exists in the measured values of this ratio. Possibly the variations found are real but analogous to those experienced in atomic heats in their relation to Dulong and Petit's law. Whatever the explanation, known difficulties due to surface transition layers seem to justify a tentative assumption of constancy for the purpose of testing theories of the origin of radiation.

Duane's hypothesis,[1] a generalization from X-ray observations, ascribes all radiation to the bombardment of atoms by moving electrons—in the ordinary temperature radiations of incandescent solids the free electrons connected with electric conduction. Starting with three fundamental assumptions, Duane concluded that Planck's distribution law results. Apparently, however, he overlooked the fact that the coefficient A in his statement of Maxwell's law is in general a function of temperature. Fortunately, however, thermionic emission experiments seem to indicate that the concentration of the free electrons in a solid varies in such a fashion, at least for low concentrations and high temperatures, if not in general, as to render the coefficient A constant for this special case.

It is to be inferred from Duane's derivation that the natural radiation from the ultimate sources has the characteristics of black body radiation for free space. This is almost certainly not the case. Black radiation in free space differs from the equilibrium radiation in an opaque solid, and only in case $\frac{k}{\lambda}$ is constant, as stated above, has this equilibrium radiation the same spectral distribution as the natural radiation from the ultimate sources.

[1] *Phys. Rev.,* **7,** 143, 1916.

Assuming the constancy of $\frac{k}{\lambda}$ and thus for the natural radiation the same spectral distribution as for equilibrium radiation, it seems necessary to modify Duane's assumption (3) so as to read *the energy radiated per hit is on the average proportional to the fourth power of the speed of the free electron and to the square of the index of refraction for the radiation emitted.* In other words,[2] *the ratio of the energy radiated per impact to the kinetic energy of the impacting electron is proportional on the average to the square of the ratio of the velocity of propagation of the radiation in the solid to that in vacuo.* On the new basis Planck's equation follows without question as to applicability.

In addition to giving certain indications regarding the application of Maxwell's law to free electrons, and pointing out the possibility of a constancy in $\frac{k}{\lambda}$, the discussion shows how Duane's hypothesis, when combined with the assumption of such constancy and with conclusions arrived at independently in other lines of research, gives a satisfying physical concept of processes which may underlie the emission of radiation by its ultimate sources.

Nela Research Laboratory of Pure Science,
Nela Park, Cleveland, Ohio.

Positive Ray Analysis of Zinc. A. J. Dempster. (*Science,* Nov. 25, 1921.)—From the Ryerson Physical Laboratory comes the announcement that zinc has been found to consist of four isotopes of respective atomic weights—63, 65, 67 and 69. The relative intensities in the same order are 6:7:10:1 From these atomic weights of the isotopes and the proportions in which they occur in ordinary zinc the atomic weight of the latter is calculated to be 65.5.

<div align="right">G. F. S.</div>

On the Theory of Relativity and the Experiment of Sagnac. P. Langevin. (*Comptes Rendus,* Nov. 7, 1921.)—Sagnac caused two rays of light from the same source to interfere after they had traversed a closed circuit in opposite directions. When the entire optical system was set in rotation the interference fringes were shifted by an amount which corresponded to an apparent difference between the times required to traverse the circuit in the two directions. Langevin derives Sagnac's exact expression for this time difference, founding his argument on the Theory of Relativity.

<div align="right">G. F. S.</div>

---

[2] As reworded by the writer's colleague, Dr. E. Q. Adams.

The Stability of Atoms. Sir Ernest Rutherford. (*Proc., Phys. Soc.,* Aug. 15, 1921.)—The mid-Victorian belief in the immutability of the atom even when subjected to " the most drastic physical and chemical agencies available " had, of course, to be discarded at the beginning of the present century when the spontaneous transformation of some of the heavier elements was established.

About the positively charged nucleus of the atom there is a distribution of enough negatively charged electrons to make the entire atom neutral. One or more of these may be detached without causing a lasting change in the atom. " In order to produce a permanent transformation of the atom it is necessary to disintegrate the nucleus." This is very small, having a radius not greater than 6×10^{-12} cm., but its constituent parts are held together by strong forces so that only " a few agencies are available for an attack on its structure." The alpha-particle is a very concentrated source of energy and, in the case of the heavier elements, one such particle out of 10,000 collides with the nucleus. " The case of the lighter elements, however, is much more favorable; for the repulsive forces are so much weaker that we may expect the alpha-particle to enter the nucleus structure without much loss of energy."

When hydrogen or a hydrogen compound is bombarded by a stream of alpha-particles it sometimes occurs that a hydrogen atom is driven ahead with such a velocity that it causes scintillations upon striking a zinc sulphide screen. The maximum range of such H-atoms is 29 cm. under certain conditions. When nitrogen or dry air is bombarded in like manner swiftly moving H-atoms appear, but with a range of 40 cm. This difference of range renders it impossible to ascribe the H-atoms to the presence of traces of hydrogen or of its compounds in the air or nitrogen used. From boron, fluorine, sodium, aluminium and phosphorus such swift H-atoms are ejected by the impact of the alpha-particles. The range of the atoms from aluminium is 80 cm. " It is of special interest to note that H-atoms are only liberated in elements whose mass is given by $4n + 2$ or $4n + 3$ where n is a whole number. No H-atoms are observed from elements like carbon, oxygen and sulphur, whose mass is given by $4n$." In the experiments cited only one alpha-particle in a million breaks up a nucleus.

G. F. S.

Effect of Pressure on the Thermal Conductivity of Metals. P. W. Bridgman. (*Phys. Rev.,* Aug., 1921.)—Pressures up to 12,000 kg. per sq. cm. were used with twelve metals. The conductivity of lead, tin, cadmium, and zinc is increased by the application of pressure, while for iron, copper, nickel, silver, platinum, bismuth, and antimony the opposite effect is produced, iron showing the smallest reduction and bismuth the greatest. For lead and tin pressure produces a greater relative effect on the thermal than upon the electrical conductivity.

G. F. S.

NOTES FROM THE RESEARCH LABORATORY EASTMAN KODAK COMPANY.*

THE PROPAGATION OF LIGHT IN ROTATING SYSTEMS.[1]

By L. Silberstein.

[ABSTRACT.]

A THEORETICAL investigation of the propagation of light in a reference system such as the earth which is uniformly rotating relatively to an inert system. The problem is treated on both the ether theory and on Einstein's relativity theory. Special attention is paid to the theory of a terrestrial optical experiment recently undertaken at the author's suggestion by Professor Michelson, in which the relative phase retardation due to rotation of two beams sent around an optical circuit is to be measured and which may offer a crucial test discriminating between the relativity theory and that of an ether showing partially or totally the spinning motion of the earth. The paper contains also an investigation of the shape of light rays which are shown to become curved, though inappreciably, due to the rotation of the earth.

THE EFFECTS OF SCATTERED X-RAYS IN RADIOGRAPHY.[2]

By R. B. Wilsey.

[ABSTRACT.]

THE effects of scattered X-rays upon radiographic contrast and definition were investigated and improvements given by reducing the intensity of scattered radiation and that produced by the use of intensifying screens or by a reduction of the tube voltage. The loss of contrast due to scattered radiation was found to be much greater for portions of the subject at a distance from the film than for portions close to the film. Reduction of the intensity of scattered radiation by a diaphragm produces the greatest im-

provement in contrast and definition in those parts of the subject farthest from the film and gives a greater improvement than that offered by reducing the tube voltage from a five-inch spark gap to a three-inch spark gap. Filters placed between the scattering material and the film gave no improvement in contrast. In the detection of faint differences in absorption the removal of scattered radiation gives results much superior to those of any other technique. Definition in the radiography of the thicker parts of the human body is controlled chiefly by the scattered radiation; marked improvement in definition is possible by a reduction of the scattered X-rays. Intensifying screens record the scattered radiation in slightly lesser degree than does the plain X-ray film. In radiographing through a scattered material under conditions that give poor definitions the limitations of intensifying screens in definition are of little importance, but when the definitions can be improved by a removal of scattered radiation the use of intensifying screens does affect unfavorably the definition. The most satisfactory solution of the problem of scattered radiation appears to be the Potter-Bucky diaphragm.

SIZE-FREQUENCY DISTRIBUTION OF PARTICLES OF SILVER HALIDE IN PHOTOGRAPHIC EMULSIONS AND ITS RELATION TO SENSITOMETRIC CHARACTER-ISTICS. II. METHODS OF DETERMINING SIZE-FREQUENCY DISTRIBUTION.[3]

By E. P. Wightman and S. E. Sheppard.

[ABSTRACT.]

THE various methods of determining size-frequency distribution are classified and discussed, and two methods, a quick sedimentation method and a microscopic method are described in detail and experimental data are given for these. The former depends upon the sedimentation of the halide particles in equal portions of their suspensions for increasing lengths of time, and after resuspending the sediments, counting in a hacmacytometer the number of particles in each of them. At the same time, the weights of the various sediments are found by analysis of the supernatent liquids from each, by application of Stokes' law

---

(Oden's method) or a modification of it the size-frequency can then be determined. The latter, the microscopic method, much longer and more tedious, is that of counting and measuring the projective areas of grains in random samples of emulsion which had been diluted and spread on a microscopic slide. By means of a high-power microscope with camera lucida attachment the particles were drawn and then were further magnified by projection, planimetered and classified. A typical size-frequency curve obtained by the latter method was plotted for a high-speed emulsion.

THE JELLY STRENGTH OF GELATINS AND GLUES.[*]

By S. E. Sheppard, S. S. Sweet and J. W. Scott, Jr.

[ABSTRACT.]

A TORSION dynamometer is described which was designed for the determination of the jelly strength of gelatin and glues under pure shear. The test pieces were cast cylinders. Both the " breaking load " and the percentage twist at break were determined; the product of breaking load X twist, divided by the cross-section of the test piece is taken as jelly strength. No simple relation was found to hold between the concentration of gelatin and jelly strength. Furthermore, the curves relating to these values of different commercial gelatins do not belong to a common family and frequently cut each other. Hence, jelly strength values determined for a single arbitrary concentration give a very arbitrary comparison of the jelly strengths. There appears, consequently, to be no definite relation between the jelly strength at a given concentration and the tensile strength of a dry glue joint.

Effect of the Presence of Small Quantities of Impurities on Sparking Potential in Air. Edgar Meyer. (*Ann. d. Phys.*, No. 12, 1921.)—In the experiments here considered the sparks passed between flat, parallel electrodes, 4.93 mm. apart. The air pressure was near to 3 mm. of mercury. It was found that as time passed somewhat different potential differences were required to cause the spark to pass and that these divergences failed to disappear when allowance was made for any change of gas pressure that might have taken place. When the sparking potential was about 440 volts the divergences in several instances were more than twenty volts. In vain it was sought to attribute these variations to temperature effects,

---

[*] Communication No. 96 from the Research Laboratory of the Eastman Kodak Company, published in *J. Soc. Chem. Ind.,* October, 1920, p. 1007.

to mercury vapor and to changes in the surface of the electrodes. Finally water vapor was found to be responsible. Water vapor with a pressure one-hundredth of a mm. of mercury suffices to lower the sparking potential by 80 volts. As the pressure increases from zero the lowering of voltage proceeds until from .01 to .02 mm. of mercury. As the pressure increases beyond this point the sparking potential rapidly rises. Thus is another thread in the tangled skein of the passage of electricity through gases unravelled.

In the same number of the *Annalen,* H. Stuecklein, of the University of Zurich, as well as Professor Meyer, contributes an additional paper on the same subject and confirms the results of the former investigation. When the sparking potential is determined inside of vessels of glass the hygroscopic action of this substance makes it difficult to eliminate from the contained gas the last traces of water vapor. This action is due to the alkali in the glass that is. free or loosely bound. Evacuating the vessel with a diffusion pump still leaves enough water vapor behind to influence the sparking potential. The following procedure, however, was satisfactory. The glass parts were treated with boiling water and thus made non-hygroscopic by the removal of the alkali. After the apparatus had been dried out by the passage of air there was still sufficient vapor to affect the sparking potential. The influence of the vapor disappears at last when the process of evacuation is kept up for several days, connection being meanwhile maintained with a P_2O_5 tube. With a less expenditure of time concordant sparking potentials can be obtained by the use of $CaCl_2$.

<div align="right">G. F. S.</div>

Chemical Industry in China is described by WILLIAM H. ADOLPH, of Shantung University (*Jour. Ind. and Eng. Chem.,* 1921, xiii, 1099–1102). Although raw materials are abundant, very little industrial alcohol is produced. A demand exists for plants to manufacture bleach, cement, fertilizers, soap and paints. Pyrite is abundant; and some commercial sulphuric acid is made by the lead chamber process. The Le Blanc process is used for the manufacture of soda. Certain salts, vegetable dyes, and glass have been made by crude processes since ancient times. Large deposits of coal and of ores of iron, tungsten, and antimony exist. China contains but one paper mill with modern equipment. Chrome leather is. being produced. The domestic sugar supply is obtained from both the sugar cane and the sugar beet. Dried eggs and vegetable oils are manufactured and exported. The popular demand is for articles " made in China." Intelligent Chinese look to the United States as the source of inspiration and help. The Chinese industrialists desire to equip their plants with machinery and apparatus from the United States; but such plant equipment must be adapted to meet the peculiar demands of the Chinese industry.

<div align="right">J. S. H.</div>

NOTES FROM THE U. S. BUREAU OF CHEMISTRY.*

VOLUME VARIATION OF BOTTLED FOODS.[1]

By H. Runkel and J. C. Munch.

[ABSTRACT.]

DATA on the capacity of bottles and volume of food in bottles indicate that only a small percentage of the bottles of food filled in accordance with good commercial practice should vary in quantity of contents by more than the calculated maximum variations.

Good commercial practice in bottling foods has been considered to be the attainment of conditions in the bottler's state of business in which he (a) includes in his orders for bottles the specifications as to capacity when filled to a specific height, (b) tests representative samples of every lot of bottles received, rejecting those appreciably under-capacity, (c) fills his bottles to a height determined from the results of his tests, and (d) has his labels printed with a definite, correct statement of the quantity of contents and applies them unaltered.

The calculated maximum variations in the volume of bottled foods, as given in the following table, have been computed from the weight variation allowed the blowers by the manufacturers, and by the use of the relation between the weight and volume of bottle glass.

	Calculated maximum variation in volume	
Capacity of bottles. Fl. oz.	Individual bottles. Fl. oz.	Average of representative samples. Fl. oz.
½	0.10	0.014
1	.10	.014
2	.19	.027
4	.24	.034
6	.24	.034
8	.29	.041
12	.29	.041
16	.39	.056
24	.39	.056
32	.58	.083
64	1.16	.17
128	1.94	.28

* Communicated by the Chief of the Bureau.
[1] *U. S. Dept. Agr. Bull. 1009,* issued Dec. 16, 1921.

THE OCCURRENCE OF METHYL ANTHRANILATE IN GRAPE JUICE.[2]

By Frederick B. Power and Victor K. Chesnut.

[ABSTRACT.]

Inasmuch as methyl anthranilate in a dilute form possesses a decided grape-like odor, its detection in commercial grape juice appears to have led to the conclusion on the part of some of those engaged in the control of these products that in all cases of its occurrence an artificial flavoring agent had been employed.

The authors have recently had an opportunity of examining a large number of authentic grape juices for the purpose of determining whether methyl anthranilate is a natural constituent of them (*J. Am. Chem. Soc.*, 1921, **43**, 377). It has now been shown that many varieties of the fruit contain this substance in relatively small amounts, and that it is present to the largest extent in juices expressed from grapes of the Concord type. In but few instances could it be regarded as entirely absent. The complete results of the investigation are reserved for a later communication.

THE DISTILLATION OF STUMPWOOD AND LOGGING WASTE OF WESTERN YELLOW PINE.[3]

By M. G. Donk, C. H. Shattuck, and W. D. Marshall.

[ABSTRACT.]

In coöperation with the University of Idaho, the Bureau of Chemistry undertook an investigation of the destructive distillation of logging and land-clearing waste, particularly of the yellow-pine stumps, in Idaho. The following conclusions were reached:

The only wastes from Western yellow-pine logging suitable for profitable commercial distillation are those resinous stumps which contain at least 50 per cent. or more of resinous heartwood, the resinous heartwood of stumps, dead down wood, and limbs from which the sapwood has rotted away. " Rich " stumps, containing not less than 60 per cent. of very resinous heartwood, probably can be profitably distilled in a commercial plant where the stand of such stumps is dense enough to keep a plant supplied for a number of years.

---

[2] Published in *J. Am. Chem. Soc.*, **43**: 1741 (1921).
[3] *U. S. Dept. Agr. Bull. 1003*, issued Dec. 5, 1921.

Single-retort plants, which can be dismantled and moved when necessary, are possibly most suitable for wood distillation in the West, especially in regions remote from the railroad.

The refined turpentine from western yellow-pine stumpwood has higher boiling-point limits and dries more slowly than that from southern yellow pine. Its solvent power is not less than that of wood turpentine made by the same process from longleaf yellow pine. It is suitable for many if not all of the purposes for which wood turpentine can be employed.

The refined pine oil and the crude oils obtained by distilling western yellow pine are valuable for ore recovery by the flotation process.

The crude light and heavy oils have germicidal properties approximately half as great as those of phenol, so that they are useful for shingle stains, wood preservatives, vermin killers and disinfectants.

THE ABSORPTION OF COPPER FROM THE SOIL BY POTATO PLANTS. [*]

By F. C. Cook.

[ABSTRACT.]

INSOLUBLE copper compounds present in a Bordeaux spray containing an excess of lime and in Pickering spray containing no excess of lime and a solution of sulphate of copper were added to the soil near the roots of potato plants in equal strengths and amounts at various intervals during the growing season. Analyses of samples of vines, tubers, and soil gave the following results:

The leaves of the plants grown in the soil receiving the insoluble copper (the sprays) held the largest part of the copper, the roots but little, and the stems an intermediate amount. Only traces of copper were found in the tubers.

Where the soil was treated with the copper sulphate solution the roots were injured and the normal metabolism of the vines was affected. The tubers from these roots were small and the vines stunted. In these plants the roots held more copper than the leaves.

The soluble copper sulphate added directly to the soil caused injury to the plants, but the insoluble copper compounds of the

sprays did not. The extra lime of the Bordeaux spray did not reduce the amount of copper absorbed by the plants, as compared with the Pickering spray.

Where the sprays and copper sulphate solution were added to the soil directly, practically the same amounts of copper were recovered from the soil samples. Only minute amounts of copper were found in samples of soil from sprayed potato fields.

"J" Radiation. J. A. CROWTHER. (*Phil. Mag.*, November, 1921.)—Considerable discrepancies have been found between the results obtained by different investigators of the scattering of X-rays that have seemed to indicate the existence of a type of fluorescent radiation having a wave-length much shorter than that of the K series. To this additional kind of radiation the name "J" has been given. Its existence has not, however, been generally accepted and, as the author of the present article says: "Partly because radiation of this type is not indicated by the current theory of the structure of the atom." The attitude of mind hereby indicated is scarcely scientific though it is highly complimentary to the modern geographers of the atom.

Mr. Crowther has investigated the X-rays scattered from paraffin, copper and aluminium and interprets his measurements as explicable by the emission of fluorescent radiations which for substances of low atomic number are weak in comparison with K radiations and which are further different from these in consisting of lines that are rather far apart in the spectrum.   G. F. S.

Separation of Certain Rare Elements by Means of Selenium Oxychloride. HENRY B. MERRILL, of the University of Wisconsin (*Jour. Am. Chem. Soc.*, 1921, xliii, 2378–2387), has used selenium oxychloride for the separation of columbium from tantalum, and of molybdenum from tungsten.

Columbium pentoxide is readily soluble in a boiling mixture of equal volumes of sulphuric acid and selenium oxychloride, while tantalum pentoxide dissolves but slightly in this solvent. When an excess of the pentoxide is boiled for 30 minutes with 50 c.c. of the solvent, the respective solubilities are—columbium pentoxide, 0.35 gram; tantalum pentoxide, 0.005 gram. This difference in the solubility of the two pentoxides is used for their separation from each other in analysis, and also for the preparation of the pure oxides.

When an ignited mixture of the trioxides of molybdenum and tungsten is treated with a boiling mixture of one part by volume of sulphuric acid and five parts of selenium oxychloride, the molybdenum trioxide dissolves while the tungsten trioxide remains insoluble. This separation of the two oxides is quantitative.
                    J. S. H.

NOTES FROM THE U. S. BUREAU OF MINES.*

TREATMENT OF TUNGSTEN ORES OF BOULDER COUNTY, COLORADO.

By J. P. Bonardi and J. C. Williams.

UNTIL the end of 1918, Boulder County, Colorado, ranked as one of the principal tungsten-producing districts of the world, but in August, 1919, there was practically no production, due to decline in demand, decrease in price, and large importations. The tungsten in this district occurs almost entirely as ferberite, although some hübnerite is found. In the early development of this district, the ores were concentrated in stamp mills designed for gold ores. Present milling practice is by stage crushing and screening, each reduction is followed by concentration by means of devices best adapted to each size. As a rule the first concentration is by jigs, either of the Harz type or Richards pulsating type, the feed varies from 4 to 20 mesh, averaging 10 mesh. Jig tailings are reground by rolls, and after screening may be treated in " fine " jigs of the launder type, yielding 20-mesh product, or may be treated on " coarse " tables. Table tailings are reground and prepared for the slime tables; table middlings may be reground and passed into a middling circuit or held for separate treatment.

Crushing is carried to such an extent that when the tailings are discharged, practically all of the mineral has been liberated. A large proportion of the tails will pass a 100-mesh screen. The ore is first crushed to ¾ to 1 inch with jaw crushers, rolls are used in preparing the mill feed. Ball mills are used for regrinding, and in one mill stamps are used to regrind the mill tailings. Within the past few years stamps have been abandoned for fine crushing because of excessive sliming, and jigs introduced to save the coarse mineral. Canvas tables are installed in all the mills, except one, and their use is said to result in a recovery of about 10 per cent. of the total, although they make a low-grade product which must be tabled.

Extractions vary from 75 to 90 per cent., according to grade

---

* Communicated by the Director.

and character of ore and grade of concentrate. The concentrates are of two kinds, "crude" and "high" grade. The crude concentrate is utilized in the manufacture of ferro-tungsten and tungstic oxide, the two basic products for producing all compounds containing tungsten. All ferro-tungsten is used as a means of introducing tungsten into ferro-alloys, whereas tungstic oxide is used to produce tungsten powder and chemicals. Tungsten powder is extensively used for introducing tungsten into ferro and other alloys.

The high-grade concentrate—60 per cent. WO_3 or more—is desirable for the manufacture of ferro-tungsten. In making tungsten oxide, by the hydrochloric acid process, the material may range from 20 to 40 per cent. WO_3, but in the soda fusion process, a higher grade, 40 to 50 per cent. is desired, although at one plant ore mining as low as 12 per cent. is used in a fusion process.

Further details are given in Bulletin 187, recently issued by the Bureau of Mines.

METHANE IN CALIFORNIA GOLD MINES.

By Byron O. Pickard and E. D. Gardner.

METHANE is well known to coal miners but it means nothing to the average gold miner, as it is not associated generally with gold-bearing formations. In a recent study of mine air in typical gold mines on the Pacific coast, three out of five California mines showed methane in ignitable quantity. In another California mine not sampled, the superintendent was seriously burned by the ignition of a pocket of gas. One of the three mines mentioned is an old mine that had been abandoned for years but was recently unwatered. Bubbles formed freely on the water, and two men were seriously burned. When sampled, the mine was supposed to be free of methane, but six samples all showed small amounts, 0.04 to 0.07 per cent. In the second mine samples showed 0.01 to 0.21 in different places, and several weeks later two men were seriously burned by igniting gas. The third mine has had small amounts of methane for years, the gas coming from a fractured zone, but care has prevented any serious accidents. Samples of the air showed 0.01 to 0.32 per cent., and near the feeders, 11.6 to 13.5 per cent.

The conclusion is that the methane is given off from certain

carbonaceous rocks associated with the gold-bearing deposits, also that it may be given off from timbers decomposing under water. Steps to insure thorough ventilation and removal of the gas should be taken in any mine where these conditions are present. Further details are given in a recent paper issued by the Bureau.

INSPECTING AND ASSEMBLING FLAME SAFETY LAMPS.

By L. C. Ilsley.

During the last few months in the anthracite fields, several explosions resulting in burnings and fatalities, were found to be undoubtedly caused by the use of defective or improperly assembled safety lamps. In nearly every coal-mining country, bonnetted lamps have superseded the unbonnetted types, and while much safer, require more care in assembling because of the greater number of parts.

Further details, with rules for the proper inspection and method of assembling safety lamps, are presented in a recent paper by the Bureau.

A Routine Method for Sulphites. Albert E. Parkes describes in the October *Analyst*, a method applicable for the detection of small amount of sulphites in food articles. It is a modification of the combined methods of Schmidt (*Arbeiten aus dem Kaiserlichen Gesundheitsamte*, 21, 226) and of Winton and Bailey (*J. Amer. Chem. Soc.*, 1907, 29, 1499), and in practice has been found to be speedy, sensitive, and efficient, without the disadvantages of the better-known method of reduction by means of zinc to hydrogen sulphide (*U. S. Dept. Agr. Bul. 107*, A.O.A.C.).

Ten grams of the material, such as dried fruit or minced meat or fish, are incorporated with 10 to 20 c.c. of water, by means of a pestle and mortar, and transferred to a small conical flask of about 50 c.c. capacity. In the case of fruit-pulp, glucose-syrup or fruit juice, 10 c.c. may be diluted, when necessary, with 10 to 20 c.c. of water in the flask.

Ten c.c. of dilute sulphuric acid of about 2N-strength and two or three small fragments of marble chips are now introduced into the flask, and the mouth immediately covered with a piece of starch paper (impregnated with a 1 per cent. starch solution), which should be screwed round the neck of the flask, and held in place with a rubber ring. The addition of the marble is to set up a gentle current of carbon dioxide to sweep out the oxygen and the liberated sulphur dioxide. The top of the paper is moistened with one drop of a 1 per cent. solution of iodine.

In the presence of any appreciable quantity of sulphites the blue stain on the starch paper will be immediately discharged by the sulphur dioxide. If traces only be present, it may take a few minutes. The action takes place in the cold; it may be hastened by leaving the flask in a warm place.

If the drop of iodine solution used be of the magnitude of 0.1 c.c. it is obvious that the limit of sensitiveness of the test is the quantity of sulphur dioxide necessary to reduce the iodine and discharge the blue color—namely, 0.00025 gram; and this is the limit usually found when using known amounts of sulphites, showing that practically the whole of the liberated gas is driven out of the flask. This amount, if 10 grams of the material are taken, would represent 0.0025 per cent. of sulphur dioxide.

By using a weaker solution of iodine the test could be made more sensitive, but for a routine qualitative test the strength suggested makes it sufficiently delicate.

Traces of hydrogen sulphide do not seriously interfere with this method, but in practice 1 c.c. of a 5 per cent. solution of copper sulphate is added to the other ingredients when testing meat or fish, and this will retain as much hydrogen sulphide as is likely to be present.

Determination of the Thorium Content of Monazite Sand by Measurement of the Emanation. HOMER H. HELMICK, of the University of Chicago (*Jour. Am. Chem. Soc.*, 1921, xliii, 2003–2014), has devised a method for the determination of the thorium content of monazite sand by measurement of its emanation by means of an electroscope. Two grams of the sand are decomposed by fusion in a platinum crucible with potassium hydrogen fluoride and metaphosphoric acid. The fused mass is permitted to cool, then is dissolved in concentrated orthophosphoric acid. Air is drawn through the resulting solution to remove the emanation, and is then passed through an ionization chamber where the emanation acts upon a charged electroscope. The time required to discharge the electroscope is noted. The determination is repeated, using a standard sample the thorium content of which has been ascertained by gravimetric analysis. A control or blank experiment is also made on the reagents. X, the per cent. of thorium in the unknown, is obtained by solution of the following equation in which A is the per cent. of thorium in the standard, T_s the period of time required for discharge of the electroscope by the standard, T_u the period of time required for discharge of the electroscope by the unknown, and T_b the period of time required for discharge of the electroscope by the blank. $X = A \dfrac{T_s (T_b - T_u)}{T_u (T_b - T_s)}$

J. S. H.

THE FRANKLIN INSTITUTE.

(Proceedings of the Annual Meeting held Wednesday, January 18, 1922.)

HALL OF THE FRANKLIN INSTITUTE,

PHILADELPHIA, January 18, 1922.

DR. WALTON CLARK, *President of the Institute, in the Chair.*

The Board of Managers submitted its report. The report recorded the election to life membership of George Wood Furness, Esquire, and the election to associate membership of Joseph Bernard King, Jr., Esquire; lectures before Sections by Erskine D. Williamson, B.Sc., M.A., Physical Chemist, Geophysical Laboratory, Carnegie Institution, Washington, D. C., on "Change of the Physical Properties of Materials with Pressure," by W. J. Humphreys, C.E., Ph.D., Professor of Meteorological Physics, United States Weather Bureau, Washington, D. C., on "Fogs and Clouds," and by Ralph H. McKee, Ph.D, Professor of Chemical Engineering, Columbia University, New York City, on "Gasoline from Oil Shale"; lecture before the Stated Meeting December 21, 1921, by P. H. Bates, A.B., B.S., Chief, Structural and Miscellaneous Materials Division, Bureau of Standards, Washington, D. C., on "The Application of the Fundamental Knowledge of Portland Cement to its Manufacture and Use"; additions to the library by gift, 60 volumes and 248 pamphlets, by purchase 12 volumes; and contained an extended report by Mr. Charles Day, Chairman of the Bartol Research Foundation Committee of the Institute; and the report of The Franklin Fund and Building Committee, together with the following resolutions:

Resolved, That the Board of Managers of The Franklin Institute recommend to the Institute the election to Honorary Membership of Professor Sir Joseph John Thomson, Master of Trinity College, Cambridge, England, who on the 4th day of January was awarded the Institute's Franklin Medal in recognition of the immeasurable service he has rendered to the world as teacher and leader of thought in that domain of science especially related to a fundamental knowledge of electricity and the constitution of matter.

Resolved, That the Board of Managers of The Franklin Institute recommend to the Institute the election to Honorary Membership of Dr. Ralph Modjeski, of New York City and Philadelphia, who on the 4th day of January was awarded the Institute's Franklin Medal in recognition of his signal achievements as a designer and builder of structures, mainly bridges, many of them epoch marking in the history of the engineering

profession, beautiful as well as useful, involving on the part of the designer, vision, courage and technique of the highest order.

Resolved, That the Board of Managers of The Franklin Institute recommend to the Institute the election to Honorary Membership of Admiral William S. Sims, U. S. N., who commanded the American Naval Forces in European waters during the world war, in recognition of his signal success in the use of scientific and technical methods and means in naval warfare.

On motion duly seconded the report was accepted and the recommendations to elect to Honorary Membership Professor Sir Joseph John Thomson, Dr. Ralph Modjeski and Admiral William S. Sims were unanimously adopted.

The tellers of election, Messers. Hoadly, Picolet and Jennings reported the ballots cast for President, Vice-president, Treasurer and members of the Board of Managers showed that the following gentlemen were elected to the respective offices indicated:

Walton Clark, D.Sc., President (to serve one year).

Henry Howson, Vice-president (to serve three years).

Benjamin Franklin, Treasurer (to serve one year).

Francis T. Chambers, W. C. L. Eglin, Alfred C. Harrison, Nathan Hayward, Charles A. Hexamer, Robert W. Lesley, Marshall S. Morgan, E. H. Sanborn, Managers (to serve three years).

Clarence A. Hall and Haseltine Smith, Managers (to serve two years).

The President read the annual report of the Board of Managers for the fiscal year ending September 30, 1921, commenting upon the reports of the various standing committees of the Institute and of the Board of Managers and detailed at some length the Institute's Parkway building program including the erection, in the near future, of a research laboratory.

The paper of the evening on "The Highway System of the State of Pennsylvania" was presented by the Honorable William D. B. Ainey, LL.D., L.H.D., Chairman of the Public Service Commission of Pennsylvania. Consideration was given to the subject of transportation as a factor in national development and the importance of highways as transportation means. An outline was given of the historical development of highway construction programmes as well as the beginnings and accomplishments of the State Highway System. Brief reference was also made to the past, present and future bearing upon the economic conditions of the State. At the close of his remarks, the speaker called upon Mr. Harold E. Hilts, Assistant Engineer of the Construction Division, State Highway Department, who exhibited a series of lantern photographs of machinery and apparatus used in the construction of roads, as well as a number of views of completed roads in various parts of the state. He described the materials used in road building and the methods of their application. At the close of the meeting a unanimous vote of thanks was extended to Doctor Ainey and Mr. Hilts for their interesting papers.

Adjourned.

R. B. Owens,
Secretary.

COMMITTEE ON SCIENCE AND THE ARTS.

(Abstract of Proceedings of the Stated Meeting held Wednesday, January 4, 1922.)

HALL OF THE INSTITUTE,
PHILADELPHIA, January 4, 1922.

MR. C. W. MASLAND, *in the Chair.*

The following report was presented for final action:

No. 2781 ⎱ The Franklin Medal. The Franklin Medal to Dr. Ralph
  and ⎰ Modjeski of New York and Sir Joseph John Thomson
No. 2782 ⎰ of England.

The following reports were presented for first reading:

No. 2775: Automatic Die Cutting Machine.

No. 2776: Milo-Lite. Dismissed without prejudice.

R. B. OWENS,
Secretary.

SECTIONS.

Section of Physics and Chemistry.—A meeting of the Section was held in the Hall of the Institute on Thursday evening, December eighth, at 8 o'clock. Dr. George F. Stradling in the Chair.

The paper of the evening on "The Precise Measurement of Small Time Intervals" was read by Dr. E. A. Eckhardt, Chief of the Sound Section, Bureau of Standards, Washington, District of Columbia. An account was given of the recent developments of the methods of and facilities for measuring small time intervals. The applicability of apparatus and methods to both scientific and industrial purposes was discussed. The applications to the measurement of linear and angular velocities and accelerations, vibration frequencies, etc., were described. The subject was illustrated by lantern slides.

After a brief discussion the thanks of the meeting were extended to Doctor Eckhardt.

Adjourned. ALFRED RIGLING,
Acting Secretary.

Section of Physics and Chemistry.—A meeting of the Section was held in the Hall of the Institute on Thursday evening, December 15, 1921, at 8 o'clock. Dr. H. Jermain M. Creighton in the Chair. The minutes of the previous meeting were read and approved.

Erskine D. Williamson, A.M., B.S., Physical Chemist, Geophysical Laboratory, Carnegie Institution, Washington, D. C., delivered a lecture on "Change of the Physical Properties of Materials with Pressure." The apparatus used to obtain hydrostatic pressures as high as 150,000 pounds per square inch was described. A resumé was given of the changes in certain fundamental electrical and elastic constants produced by the application of high pressures. The lecture was illustrated with lantern slides and a model of the apparatus. The paper was discussed by Doctor Manzies, Mr. Williamson and others. On motion of Doctor Barnes and Mr. Bonine, a vote of thanks was extended to Mr. Williamson. The meeting then adjourned.

JOSEPH S. HEPBURN,
Secretary.

Section of Physics and Chemistry.—A meeting of the Section was held in the Hall of the Institute on Thursday evening, January 5, 1922. The meeting was called to order by Mr. Coleman Sellers, Jr., Vice-president of the Institute.

The paper of the evening on "Fogs and Clouds" was presented by W. J. Humphreys, C.E., Ph.D., Professor of Meteorological Physics, United States Weather Bureau, Washington, D. C. The principal types of fogs and clouds were discussed and their mode of formation and significance explained. Interesting facts were given concerning the size of fog and cloud particles; the number of them per given volume; why the air as a whole is never saturated; how clouds float, and how rain is produced; how the altitudes and velocities of clouds are measured; and other such matters concerning these fascinating phenomena of the sky. The subject was illustrated by numerous lantern slides.

After a discussion in which Doctor Stradling, Mr. Wetherill and others participated, the unanimous thanks of the meeting were extended to Doctor Humphreys. Adjourned.

ALFRED RIGLING,
Acting Secretary.

MEMBERSHIP NOTES.

ELECTIONS TO MEMBERSHIP.

(Stated Meeting, Board of Managers, January 11, 1922.)

LIFE MEMBERSHIP.

MR. GEORGE WOOD FURNESS, Jenkintown, Pennsylvania.

ASSOCIATE.

MR. JOSEPH B. KING, JR., The Electric Storage Battery Company, Philadelphia, Pennsylvania.

CHANGES OF ADDRESS.

MR. WALTER ATLEE, 410 N. Hilton Street, Baltimore, Maryland.

MR. F. H. CLARK, Tuscany Apartments, 40th and Stony Run Road, Baltimore, Maryland.

MR. MILTON W. FRANKLIN, General Motors Research Corporation, Dayton, Ohio.

MR. W. L. GARRELS, Manchester, Missouri.

MR. J. H. GRANBERY, 234 West 21st Street, New York City, New York.

DR. CHARLES H. HERTY, Room 343, 1 Madison Avenue, New York City, New York.

DR. WILBUR M. STINE, 3932 Haverford Avenue, Philadelphia, Pennsylvania.

MR. ORIN C. STOUT, 207 Commerce Building, Columbus, Ohio.

MR. E. R. WHITNEY, Commercial Truck Company, Hunting Park and Rising Sun Avenues, Philadelphia, Pennsylvania.

NECROLOGY.

Dr. William Frear, State College, Pennsylvania.

LIBRARY NOTES.
PURCHASES.

CALLENDAR, M. A.,—Properties of Steam and Thermodynamic Theory of Turbines. 1920.

CAMPBELL, NORMAN ROBERT.—Physics, the Elements. 1920.

CARLIER, ANDRÉ H.,—La Photographie Aérienne Pendant la Guerre. 1921.

Federated American Engineering Societies.—Waste in Industry. 1921.

MOORE, BENJAMIN.—Biochemistry. A Study of the Origin, Reactions and Equilibra of Living Matter. 1921.

MOUREU, CHARLES.—La Chimie et la Guerre Science et Avenir. 1920.

PACOTTE, JULIEN.—La Physique Théorique Nouvelle. 1921.

THORPE, SIR EDWARD.—Dictionary of Applied Chemistry, 2 volumes. 1921.

WALKER, MILES.—The Diagnosing of Troubles in Electrical Machines. 1921.

GIFTS.

Abrasive Company, Abrasive Grinding Wheels. Philadelphia, Pennsylvania, 1919. (From the Company.)

Acme Machine Tool Company, Catalogue of Acme Flat Turret Lathes. Cincinnati, Ohio, no date. (From the Company.)

Adams Company, Catalogues 104, 105, 106, 125. Dubuque, Iowa, no date. (From the Company.)

Allegheny Steel Company, Allegheny Steel and Iron Products. Pittsburgh, Pennsylvania, no date. (From the Company.)

Allen-Bradley Company, Bulletin J-1552. Milwaukee, Wisconsin, 1921. (From the Company.)

Allis-Chalmers Manufacturing Company, Bulletin 1118, Polyphase Induction Motors. Milwaukee, Wisconsin, 1921. (From the Company.)

American Hoist and Derrick Company, American Material Handling Machinery for Industrial Plants. New York City, New York, no date. (From the Company.)

American Radiator Company, Booklets of Natural and Artificial Gas Boilers, Round and Square Boilers, Ideal Water Tube Boiler, Sectional Boilers, Peerless Wall Radiators and Engineers' Data on Vento Heaters. Chicago, Illinois, no date. (From the Company.)

American Steam Pump Company, Pumping Machinery. Battle Creek, Michigan, no date. (From the Company.)

Ames Iron Works, Bulletin No. 1000 of Boilers for Every Service. Oswego, New York, 1921. (From the Works.)

Anderson, V. D., Company, Anderson Steam Specialties. Cleveland, Ohio, 1921. (From the Company.)

Autovent Fan and Blower Company, Modern Ventilating Apparatus. Chicago, Illinois, 1921. (From the Company.)

Bailey Meter Company, Bulletins 42 and 60. Cleveland, Ohio, 1921. (From the Company.)

Ball and Roller Bearing Company, Bulletin No. 110. Danbury, Connecticut, no date. (From the Company.)

Bartlett, C. O., and Snow Company, Bulletin 47, Ideas. Cleveland, Ohio, 1921. (From the Company.)

Bethlehem Shipbuilding Corporation, Ltd., Catalogues DA, F-1, O, VI, WA and WB. Bethlehem, Pennsylvania, 1921. (From the Corporation.)

Bignall and Keeler Machine Works, Pipe Machines. Edwardsville, Illinois, no date. (From the Works.)

Bridgeport Safety Emery Wheel Company, Inc., Catalogue C of Grinding Wheels. Bridgeport, Connecticut, no date. (From the Company.)

British Lighting and Ignition Company, Ltd., Instruction Book for Starting, Lighting and Dynamo Ignition. Birmingham, England, no date. (From the Company.)

Brown Instrument Company, Bulletins of Pyrometers. Philadelphia, Pennsylvania, no date. (From the Company.)

Brush Electrical Engineering Company, Ltd., Brush-Ljungstrom Steam Turbines ·and Turbo-Generators. London, England, no date. (From the Company.)

Buckeye Machine Company, Bulletins 301, 302, 303, 305, 307 and 308. Lima, Ohio, no date. (From the Company.)

Burke Machine Tool Company, Catalogue of Milling Machines. Conneaut, Ohio, no date. (From the Company.)

Canada Department of the Interior, Annual Report of the Reclamation Service. Ottawa, Canada, 1921. (From the Department.)

Canada Department of Mines, Summary Report, 1920, Part D, Memoir 125 on Sedimentation of the Fraser River Delta, and Bulletin 33, Pamphlet 564, The Preparation, Transportation and Combustion of Powdered Coal. Ottawa, Canada, 1921. (From the Department.)

Case School of Applied Science, Catalogue 1921-1922. Cleveland, Ohio, 1921. (From the School.)

Celite Products Company, Heat Insulation Folder, 1093. Philadelphia, Pennsylvania, 1921. (From the Company.)

Chapman Engineering Company, Chapman Gas Producers, Erecting and Operating Instructions. Mt. Vernon, Ohio, no date. (From the Company.)

Chicago Bureau of Railway News and Statistics, Railway Statistics of the United States for 1920. Chicago, Illinois, 1921. (From Mr. Slason Thompson.)

Chicago Mill and Lumber Company, "Boxes" for November, 1921. Chicago, Illinois. (From the Company.)

Chicago Pneumatic Tool Company, Bulletin 710. Chicago, Illinois, no date. (From the Company.)

Clark Dust Collecting Company, Bulletin C-10. Chicago, Illinois, no date. (From the Company.)

Clayton and Shuttleworth, Limited, Crude Oil Engines. Lincoln, England, no date. (From the Company.)

Cooper, C. and G., Company, Bulletin No. 54. Mt. Vernon, Ohio, no date. (From the Company.)

Coventry Victor Motor Company, Ltd., Catalogue No. 6. London, England, 1920. (From the Company.)

Crane Packing Company, Metallic Packing. New York City, New York, no date. (From the Company.)

Cuerpo de Ingenieros de Minas y Aguas, Anales del Congreso Nacional de la
    Industria Minera, Tomo vii and viii. Lima, Peru, 1920. (From the
    Corps of Engineers.)

Davis-Bournonville Company, Welding and Cutting. Jersey City, New Jersey,
    no date. (From the Company.)

Dempsey Cycle Company, Inc., A New Gas Engine Cycle Pamphlet. Phila-
    delphia, Pennsylvania, no date. (From the Company.)

Diamond Power Specialty Company, Bulletins 119, 132 and 137. Detroit,
    Michigan, 1921. (From the Company.)

Edison Lamp Works, Ship Lighting. Harrison, New Jersey, 1921. (From
    the Works.)

Elliott Company, Bulletin K on Self-Cleaning Blow-off Valve. Pittsburgh,
    Pennsylvania, 1921. (From the Company.)

Firth, Thomas, and Sons, Ltd., Crucible Carbon and High-speed Tool Steels
    and Carbon and Alloy Steels. Sheffield, England, no date. (From the
    Company.)

Fisher Governor Company, Bulletin Catalogue of Power Plant Specialties.
    Marshalltown, Iowa, no date. (From the Company.)

Fulton Company, Sylphon Specialties. Knoxville, Tennessee, 1921. (From
    the Company.)

Godfrey Conveyor Company, Godfrey Conveyors. Elkhart, Indiana, no date.
    (From the Company.)

Gold Car Heating and Lighting Company, Booklet of Temperature Regulating
    Systems. Brooklyn, New York, 1921. (From the Company.)

Gordon, Robert, Inc., Mechanical Hot Blast Heaters and Which Heating
    System and Why. Chicago, Illinois, 1921. (From the Company.)

Great Britain Meteorological Office, Geophysical Memoirs Nos. 17 and 18.
    London, England, 1921. (From the Office.)

Griscom-Russell Company, Raw Water Distilling Plants. New York City,
    New York, 1920. (From the Company.)

Haines, William S., and Company, Blue Prints of Typical Installations of
    the Haines Automatic Valves and Traps. Philadelphia, Pennsylvania,
    1921. (From the Company.)

Harvard College Astronomical Observatory, Seventy-fifth Annual Report of
    the Director. Cambridge, Massachusetts, 1921. (From the Director.)

Heil Company, Catalogue No. 120 of Tanks. Milwaukee, Wisconsin, no date.
    (From the Company.)

Hercules Powder Company, The Hercules Mixer. Wilmington, Delaware,
    1921. (From the Company.)

Herschel, Clemens, The Water Supply of the City of Rome of Sextus Julius
    Frontinus. New York City, New York, 1913. (From the Author.)

Heywood, S. H., and Company, Ltd., Electric Lifts. Reddish, England, no
    date. (From the Company.)

Hobart College, Catalogue 1921-1922. Geneva, New York, 1921. (From the
    College.)

Hodgson, R. B., and Company, Ltd., Catalogues of Crucible Tool Steels.
    Sheffield, England, 1921. (From the Company.)

Hoefer Manufacturing Company, Catalogues "B" and "H." Freeport, Illinois, 1921. (From the Company.)

Hoppes Manufacturing Company, Catalogue 75 on Water Heaters. Springfield, Ohio, 1921. (From the Company.)

Hoskins Manufacturing Company, Catalogues 13, 31-R, 80, 91, 102, 121. Detroit, Michigan, no date. (From the Company.)

Howden, James, and Company, Bulletin No. A-3 of High-speed Engines. Wellsville, New York, no date. (From the Company.)

Howlett Construction Company, Small Locomotive Coaling Station. Moline, Illinois, no date. (From the Company.)

Hunt, C. W., Company, Inc., Catalogues 20-1 and 21-1 of Coal and Ash Gates. West New Brighton, New York, 1921. (From the Company.)

Ingersoll Milling Machine Company, Bulletin 41. Rockford, Illinois, no date. (From the Company.)

Ingersoll-Rand Company, Catalogue of Ingersoll-Rand Products. New York City, New York, 1921. (From the Company.)

Institution of Engineers and Shipbuilders, Transactions, Sixty-fourth Session. Glasgow, Scotland, 1921. (From the Secretary.)

Iowa Engineering Society, Proceedings of the Thirty-third Annual Meeting. Des Moines, Iowa, 1921. (From the Secretary-Treasurer.)

Jones, A. A., and Shipman, Ltd., Handbook of Tool Room Grinding, Book 17 on Precision Grinding and Booklet of Grinders. Leicester, England, no date. (From the Company.)

Kelly Foundry and Machine Company, Catalogue C and H. Goshen, Indiana, 1921. (From the Company.)

Kenyon, William, and Sons, Ltd., Transmission of Power by Ropes. Dukinfield, England, 1921. (From the Company.)

Kingsbury Manufacturing Company, Bulletin No. 2, of Drilling Machinery. Keene, New Hampshire, no date. (From the Company.)

Knox College, College Catalogues, 1913 to 1921. Galesburg, Illinois. (From the College.)

Kryn and Lahy Metal Works, Ltd., Steel Castings. Letchworth, England, no date. (From the Works.)

Lidgerwood Manufacturing Company, Lidgerwood Marine Machinery. New York City, New York, 1919. (From the Company.)

London Meteorological Office, Annual Report for 1920. London, England, 1921. (From the Office.)

Magor Car Corporation, Catalogue No. 100. New York City, New York, 1921. (From the Corporation.)

Manchester Steam Users' Association, Thirty-fourth Annual Report upon the Working of the Boiler Explosions Act of 1882. Manchester, England, 1920. (From Mr. C. E. Stromeyer.)

Marion Steam Shovel Company, Catalogue 190 of Excavating Machinery. Marion, Ohio, no date. (From the Company.)

Massachusetts Institute of Technology, Acoustic Impedance and Its Measurement. Boston, Massachusetts, 1921. (From the Institute.)

Meuris, A. C., Partie des L'Aimantation. Brussels, France, 1921. (From M. Meuris.)

Mills, Rhines, Bellman and Nordhoff, Industrial Buildings. Toledo, Ohio, 1921. (From the Company.)

National Tube Company, Bulletin 13 of National Hammer-Weld Pipe. Pittsburgh, Pennsylvania, 1921. (From the Company.)

Nebraska State Railway Commission, Thirteenth Annual Report. Aurora, Nebraska, 1921. (From the Commission.)

New England Tank and Tower Company, Bulletins Nos. A120, A121. Everett, Massachusetts, no date. (From the Company.)

Norwalk Iron Works Company, Bulletin No. 1 of Compressors for Oxygen and Hydrogen. South Norwalk, Connecticut, no date. (From the Company.)

Oldham, George, and Son Company, Oldham Pneumatic Tools. Baltimore, Maryland, no date. (From the Company.)

Pennsylvania Tank Car Company, The Tank Car. Sharon, Pennsylvania, no date. (From the Company.)

Pignolet Instrument Company, Bulletin No. 21A of Electric Measuring Instruments. New York City, New York, 1921. (From the Company.)

Portland Cement Association, Concrete Bins and Pits for Coal Storage. Portland, Oregon, no date. (From the Association.)

Potter, S. A., Tool and Machine Works, Catalogue No. 10. New York City, New York, no date. (From the Company.)

Powers Regulator Company, Bulletins Nos. 124, 129, 137, 138, 147 and 150. New York City, New York, 1921. (From the Company.)

Pratt and Whitney Company, Circular No. 269 of Vertical Shapers. Hartford, Connecticut, no date. (From the Company.)

Rawson Electrical Instrument Company, Rawson Single-Pivot Meters, Bulletin 102. Cambridge, Massachusetts, no date. (From the Company.)

Redheugh Iron and Steel Company, Ltd., Catalogues on Castings. Teams, Gateshead-on-Tyne, England, no date. (From the Company.)

Rhode Island Public Utilities Commission, Ninth Annual Report. Providence, Rhode Island, 1921. (From the Commissioners.)

Richardson-Phenix Company, Bulletins 5A, 11, 25, 30, 50B and 60A, Catalogue No. 20, Keeping Steam Turbine Lubricating Oil in Good Condition and The Pump Valve that Does not Leak. Milwaukee, Wisconsin, 1921. (From the Company.)

Roberts and Schaefer Company, Bulletins 43 and 45. Chicago, Illinois, 1921. (From the Company.)

Robinson, Dwight P., Locomotive Terminals. New York City, New York, no date. (From the Company.)

Ruston and Hornsby, Ltd., Ruston Steam Boilers. Lincoln, England, no date. (From the Company.)

Sanford Riley Stoker Company, Riley Stokers. Worcester, Massachusetts, no date. (From the Company.)

Saunders, D., Sons, Catalogue H, Pipe-Threading and Cutting Machinery. Yonkers, New York, no date. (From the Company.)

Schutte and Koerting Company, Catalogue 6 of Fuel Oil Burning System. Philadelphia, Pennsylvania, no date. (From the Company.)

Schweitzer and Conrad, Inc., Bulletins 103-A and 106-A of Fuses and Ejector Cutouts. Chicago, Illinois, no date. (From the Company.)

Scientific Materials Company, Bulletin 100 of Fisher Burners. Pittsburgh, Pennsylvania, no date. (From the Company.)

Siemens Brothers and Company, Ltd., Catalogue 190 of Ebonite. London, England, 1921. (From the Company.)

Simon, F. Lester, Dredging Engineering. New York City, New York, 1920. (From Mr. Nathan Hayward.)

Smith and Coventry, Ltd., Pamphlet Section J. of Spiral Bevel Gear Planer. Manchester, England, no date. (From the Company.)

Squires, C. E., Company, Squires Boilers and Valves. Cleveland, Ohio, 1916. (From the Company.)

Standard Pressed Steel Company, Booklet of Hallowell Steel Bench Legs. Jenkintown, Pennsylvania, no date. (From the Company.)

Stanford University, Register 1920-1921. Stanford University, California, 1920. (From the University.)

Stearns Conveyor Company, Bulletin 100 of Material Handling Methods. Cleveland, Ohio, no date. (From the Company.)

Stromberg Electric Company, Catalogue No. 214. Chicago, Illinois, 1921. (From the Company.)

Sturtevant, B. F., Company, Catalogue No. 230 on Heaters. Hyde Park, Boston, Massachusetts, 1920. (From the Company.)

Thompson Grinder Company, Bulletin U-13. Springfield, Ohio, 1920. (From the Company.)

Troy Laundry Machinery Company, Ltd., The Problems of the Laundry Power Plant. Chicago, Illinois, 1921. (From the Company.)

Turbine Sewer Machine Company, Sewer Cleaning Equipment. Milwaukee, Wisconsin, no date. (From the Company.)

United States Army, Report of the Surgeon General for 1921. Washington, District of Columbia, 1921. (From the Secretary of War.)

United States Department of Agriculture, Bulletin No. 995. Washington, District of Columbia, 1921. (From the Department.)

University of British Columbia, Calendars for 1918 to 1922. Vancouver, British Columbia. (From the University.)

University of California, Registers for 1911-1920 inclusive. Berkeley, California. (From the University.)

University of Colorado, Catalogue, 1919-1920. Boulder, Colorado, 1920. (From the University.)

University of Delaware, Bulletin No. 1, Vol. 17. Newark, Delaware, 1921. (From the University.)

University of Kansas, Annual Catalogue 1920-1921. Lawrence, Kansas, 1920. (From the University.)

University of Michigan, General Announcement 1921-1922 and College of Literature, Science and the Arts, Annual Announcement, 1921-1922. Ann Arbor, Michigan, 1921. (From the University.)

University of Minnesota, General Information 1921-1922. Minneapolis, Minnesota, 1921. (From the University.)

University of Pennsylvania, Catalogue 1920-1921. Philadelphia, Pennsylvania, 1920. (From the University.)

University of the State of New York, Annual Reports of the Board of Education for 1918 and 1919. Albany, New York. (From the New York State Library.)

University of Montana, Annual Catalogues, 1917 to 1921. Missoula, Montana. (From the University.)

Union Steam Pump Company, Booklet No. 102, Pumping Machinery. Battle Creek, Michigan, 1921. (From the Company.)

Vickers-Petters, Limited, General Catalogue of Crude Oil Engines for Land and Sea. Ipswich, England. 1921. (From the Company.)

Wadleigh, F. R., A Coal Manual for Salesmen, Buyers and Users. Cincinnati, Ohio, 1921. (From the Author.)

Westinghouse Brake and Saxby Signal Company, Ltd., Electro-pneumatic Control Safety Appliances for Collieries. London, England, 1921. (From the Company.)

White, Thomas, and Sons, Ltd., Booklet of Automatic Machine Tools. Paisley, Scotland, no date. (From the Company.)

Whiting Corporation, Whiting Cranes, Catalogue 158. Harvey, Illinois, 1921. (From the Corporation.)

Williams, D. T., Valve Company, Catalogue No. 10 of Williams Specialties. Cincinnati, Ohio, 1915. (From John Maneely Company, Philadelphia, Pennsylvania.)

BOOK NOTICES.

NATIONAL ADVISORY COMMITTEE FOR AERONAUTICS. Report No. 118. The Pressure Distribution over the Horizontal Tail Surfaces of an Airplane, by F. H. Norton. 86 pages, illustrations, quarto. Washington, Government Printing Office, 1921.

The investigation is divided into three parts, of which this is the first. This part includes the complete study of the pressure distribution over two horizontal tail surfaces, one a standard JN4H tail plane, and the other of special construction, which was thicker and with a plan form of higher aspect ratio. The pressures were recorded at flight speeds of 45 miles per hour to 100 miles per hour, and at engine speeds of 600, 900, 1200, and 1400 revolutions per minute, in order to get all of the conditions that would occur in flight. At the same time various modifications were made in the airplane, such as moving the position of the centre of gravity horizontally, and varying the tail plane in angle, section, and plan form. The number of holes on the tail were so numerous (over 200) that the total pressure of the tail under any conditions could be obtained very accurately by integration of the pressure distribution curve. The results are plotted in a large variety of ways in order to bring out as clearly as possible the exact distribution of pressure.

Report No. 119. The Pressure Distribution over the Horizontal Tail Surfaces of an Airplane, II, by F. H. Norton and D. L. Bacon. 40 pages, illustrations, quarto. Washington, Government Printing Office, 1921.

This investigation was undertaken in order to determine whether the results obtained upon model tail surfaces can be used to accurately predict loads

upon the full-sized tail, and also to find the distribution of load when large elevator angles are used, as the loads from such angles cannot be obtained readily in free flight. The method consisted in using a metal horizontal tail surface inside of which small air passages, connecting with a series of holes in the surface, led the pressure off from the tail in rubber tubes. In this way the pressure at each of these holes was measured by a manometer at several angles of attack and several elevator settings. The results show that the model tests give a loading which is equivalent to the loading under similar conditions in the full-sized airplane and that the manner of distribution is quite similar in the two cases when there is no slip stream.

Report No. 124. Aerodynamic Characteristics of Aerofoils, II, Continuation of Report No. 93. 65 pages, illustrations, quarto. Washington, Government Printing Office, 1921.

This collection of data on aerofoils has been made from the published reports of a number of the leading aerodynamic laboratories of this country and Europe. The information which was originally expressed according to the different customs of the several laboratories is here presented in a uniform series of charts and tables suitable for the use of designing engineers and for purposes of general reference.

It is a well-known fact that the results obtained in different laboratories, because of their individual methods of testing, are not strictly comparable even if proper scale corrections for size of model and speed of test are supplied. It is, therefore, unwise to compare too closely the coefficients of two wing sections tested in different laboratories. Tests of different wing sections from the same source, however, may be relied on to give true relative values.

The absolute system of coefficients has been used, since it is thought by the Committee that this system is the one most suited for international use and yet is one for which a desired transformation can be easily made. For this purpose a set of transformation constants is included in this report.

Each aerofoil section is given a reference number, and the test data are presented in the form of curves from which the coefficients can be read with sufficient accuracy for design purposes. The dimensions of the profile of each section are given at various stations along the chord in per cent. of the chord, using as datum the line shown on the curves. The shape of the section is also shown in reasonable accuracy to enable one to more clearly visualize the section under consideration, together with its characteristics.

The name of the laboratory at which the experiments were conducted is given as the authority for the results here presented, with the size of model, wind velocity, and date of test.

THE AMERICAN ANNUAL OF PHOTOGRAPHY FOR 1922. Small 8vo., 296 pages. George Murphy, Inc., New York. Paper, $1.75.

This is the 36th volume of this well-known photographic manual and exhibits the merits that have always been associated with it. It is extensively illustrated, the pictures covering all fields of photography, with, of course, the usual supply of soft focus effects and female nudes. Many articles of practical value are included. The mechanical execution is excellent.

HENRY LEFFMANN.

Bleaching and Related Processes, as applied to textile fibre and other ma-
terials. By J. Merritt Matthews, Ph.D. 8vo., xi-651 pages, bibliography,
index and 298 illustrations. The Chemical Catalog Company, New York.
$8.00 net.

The author of this book has been long favorably known in the field of
textile chemistry and is well qualified to present the subject in a clear and
comprehensive form, which he has done. The art of dyeing is a very ancient
one and the art of bleaching is necessarily associated with it. In making up
the matter, the classification has been according to the materials and not ac-
cording to the bleaching agents. Textile fibres, of course, occupy the most
prominent place in the art, and cotton stands out as a conspicious material.
The volume has been written principally to meet the requirements of the
textile chemist, approaching it from the practical applications, and not de-
voting appreciable space to the theoretical principles involved. The phenomena
of dyeing and coloring have found extensive studies under the recent develop-
ments of physical chemistry, but while theory should be correlated with prac-
tice, the problem set by this book is actual methods and not the reasons for
them. Numerous illustrations aid in understanding the methods.

The descriptive part begins with a study of wool. A brief historical note
is given in this section. The art of bleaching, though of very early origin,
was not by direct chemical means, but by the action of light and air; the
scientific methods by means of definite chemicals are of much later development.
As might be expected the first active chemical agent was chlorine, but although
Scheele discovered this in 1774, it was not until 1785 that its bleaching proper-
ties were studied with reference to their commercial application. It was not
until the dry bleaching powder, prepared first by Tennant early in the nine-
teenth century, was made commercially available that the full application of
the properties of chlorine were secured. This product became, as is well
known, one of the most important and conspicious British exports. For many
years it was made only by the direct action of chlorine on lime. The processes
of bleaching are, in general, oxidation actions, but the direct application of
oxygen has not been satisfactory, and it appears that it is the condition of im-
mediate liberation, termed commonly the "nascent state," that is effective.

The text is by no means limited to the mere details of standard bleaching
methods. A great deal of information is given as to the character of fibres,
and while the textile fibres are necessarily given the largest space, the in-
teresting and highly important question of paper-stock bleaching is given full
consideration. Bone, ivory, horn and feathers are also briefly treated. The
bulk of the descriptive matter is, of course, devoted to the treatment of the
raw materials, including not only decolorization, but the removal of other foreign
matters which interfere with either the working up or the dyeing of the fibres.
A special chapter is devoted to the removal of dyes, technically known as
"stripping." The most difficult colors to remove are alizarine and the mor-
danted ones. For stripping purposes, with most colors, the substance, termed
for want of a more systematic name "sodium hydrosulphite" is extensively used.
To the professional chemist, the most interesting and useful chapter is that
devoted to the testing of the materials used in the processes described in the

book. This covers more than one hundred pages, the numerous methods being given in careful detail. The complexity of the bleaching and related industries is shown by the many substances used in them. The chapter begins with a consideraton of the requirements of the water supply and the methods of analysis. The important data are color, total solids, suspended matter, hardness, temporary and permanent, and iron. The recommended procedure for total solids is to concentrate 1000 c.c. in porcelain basins to about 50 c.c and finish the evaporation in a porcelain or platinum dish. This is tedious and, with many waters, inaccurate, on account of the partial precipitation of certain salts, portions of which may adhere quite obstinately to the larger dish. Data accurate enough for technical analysis can be obtained by evaporating 100 c.c. in a weighed platinum dish or in lack of that, a quartz dish. The standard methods of determining hardness by soap solution and by titration with acid are described. It will, however, often be found worth while when the supply of a large plant is in question to determine the calcium and magnesium, in samples before and after boiling, by the standard quantitative methods. A note upon a class of mixture, termed in the trade "bleachers' assistants," gives the information that the articles are often mixtures of cheap chemicals, sold as great mysteries at much higher prices than they could be made for by the user. Oils and soaps which are so largely used in certain preliminary and finishing processes are treated very fully. Two salts are noted, which are comparatively recent additions to familiar chemistry, namely sodium hydro-sulphite and sodium perborate. The former is a powerful reducing agent, the latter an oxidizing agent analogous to hydrogen peroxide. Both of these salts have received unsatisfactory names. The analogy of the perborates is to the metaphosphates, and it would be more satisfactory if sodium perborate was called "metaborate." Sodium hydrosulphite shares with other oxy-sulphur salts, the confusion that has arisen from the numerous compounds of the group that have been discovered, and for which the standard nomenclature does not automatically provide. There is a disagreement between the formula that Doctor Matthews gives for sodium hydrosulphite and that given in "The Condensed Chemical Dictionary" issued by the same publishing house that issues the work now under review. The dictionary gives $Na_2S_2O_4$, Doctor Matthews gives $NaHSO_2$. There is also another discrepancy. Doctor Matthews gives several commercial forms of the hydrosulphite as "rongalite," while the dictionary applies that trade name to sodium hydrosulphide, a very different salt. The term "hydrosulphite" is unsatisfactory, and really not in accord with the general principles of inorganic nomenclature, but the long series of oxy-sulphur salts seems to defy a systematic naming.

A bibliography and a good index close the volume. The work is a valuable contribution to the literature of one of the most extensive and important industries, and reflects great credit on the author, whose long, faithful and efficient studies have fitted him to deal thoroughly with the subject.

HENRY LEFFMANN.

PUBLICATIONS RECEIVED.

Étude, Géométrique des Transformations Birationnelles et des Courbes Planes, par Henri Malet. 262 pages, illustrations, 8vo. Paris, Gauthier-Villars et Cie., 1921.   Price 32 francs.

Physique Élémentaire et Théories Modernes, par J. Villey. Première partie molécules et atomes. États d'équilibre et mouvements de la matière. (mécanique, statique des fluids, chaleur, élasticité et acoustique.) 197 pages, illustrations, 8vo. Paris, Gauthier-Villars et Cie., 1921.   Price 15 francs.

Précis d'Arithmétique, par J. Poirée.   63 pages, 8vo. Paris, Gauthier-Villars et Cie., 1921.   Price 7 francs 50.

U. S. Bureau of Mines: Bulletin 187, Treatment of the Tungsten Ores of Boulder County, Colo., by J. P. Bonardi and J. C. Williams. 79 pages, illustrations, plates, diagrams, 8vo. Miners' Safety and Health Almanac for 1922, compiled by R. C. Williams. 53 pages, illustrations, 8vo. Monthly statement of Coal-mine Fatalities in the United States, October, 1921. 8 pages, 8vo. Washington, Government Printing Office, 1921.

National Advisory Committee for Aeronautics: Technical Notes No. 74, Mutual Influence of Wings and Propeller, by L. Prandtl. 6 pages, diagrams, quarto. No. 76, A Mechanical Device for Illustrating Airplane Stability, by F. E. Norton. 5 pages, illustrations, photograph, quarto. No. 77, A Preliminary Investigation of a New Method for Testing Aerofoils in Free Flight, by F. H. Norton. 11 pages, diagrams, photograph, quarto. No. 79, Effect of Aerofoil Aspect Ratio on the Slope of the Lift Curve, by Walter S. Diehl. 4 pages, illustrations, quarto. Washington, Committee 1921-22.

Prices and Cost of Living. From the Monthly Labor Review (November, 1921) of the Bureau of Labor Statistics, United States Department of Labor. 47 pages, 8vo. Washington, Government Printing Office, 1921.

A Contribution to the Determination of the Shape of Molecules. R. GANS. (*Ann. d. Phys.,* No. 10, 1921.)—Results obtained in a study of the light sent off laterally when a beam traverses a gas joined to an interpretation furnished by the Clausius-Mossotti theory lead to definite conclusions regarding the form of the molecules of the gases under examination. Helium molecules have the form of a very elongated prolate ellipsoid, while carbon dioxide, ammonia and carbon disulphide all have two forms which are oblate and prolate ellipsoids.

This work emanates from the Instituto Física, La Plata.

G. F. S.

Heat of Formation of Silver Iodide. HUGH S. TAYLOR and WILLIAM T. ANDERSON, JR., of Princeton University (*Jour. Am. Chem. Soc.,* 1921, xliii, 2014–2017), have made calorimetric measurements of the heat produced by the reaction of silver with iodine to form silver iodide. They find that silver iodide has a heat of formation of 15,100 calories.   J. S. H.

CURRENT TOPICS.

The Artificial Disintegration of Light Elements. Sir E. Rutherford and J. Chadwick. (*Phil. Mag.*, November, 1921.)— Within the last three years the former of these authors has shown that when swift alpha-particles pass through air or nitrogen there are produced a few long-range particles capable of detection by the scintillations they cause when they impinge on a zinc sulphide screen. These particles were identified as H atoms from the fact that they were deflected by a magnetic field to the same extent as similarly moving H atoms would be deflected under similar circumstances.

The alpha-rays traveling through hydrogen develop H atoms that cause scintillations on the screen after they have passed through 29 cm. of air. When the rays, on the other hand, move through nitrogen they develop H atoms that cause scintillations on the screen after they have passed through 40 cm. of air. It is clear then that scintillations occurring at ranges greater than 29 cm. cannot be ascribed to the presence of hydrogen or of its compounds. In the present investigation an active deposit of radium C discharged alpha-rays into the substance under examination. Beyond this was the screen on which the scintillations were counted with a microscope. Definite proof was obtained that particles with ranges in excess of 29 cm. were produced from boron, fluorine, sodium, aluminium and phosphorus in addition to nitrogen. No such particles were got from lithium, beryllium, carbon, oxygen, magnesium, silicon and sulphur, nor from these elements of higher atomic weights—chlorine, potassium, titanium, manganese, iron, copper, tin, silver and gold.

When aluminium was bombarded by alpha-particles it was found that the H atoms were projected not only in the direction of the alpha-particles but also in the opposite direction. The range of the atoms in the backward direction was not so great as in the forward course, 67 against 90 cm. of air, but their number, though less, was of the same order of magnitude as in the forward direction. In the case of nitrogen the number of atoms projected backward is very small, if indeed there are any such atoms.

The H atom probably arises from the disintegration of an atomic nucleus caused by the impact of an alpha-particle. Of the elements giving rise to H atoms all have atomic weights either 2 or 3 in excess of some multiple of 4. For example, the atomic weight of sodium is 23, which equals 4 times 5 with the addition of 3. Should the nucleus be composed of several helium nuclei of mass 4 and of 1, 2 or 3 hydrogen nuclei, this structure would agree with what has just been said and also with the fact that no hydrogen atoms have been obtained from those elements, whose atomic weights are

multiples of 4, *i.e.*, carbon and oxygen, and whose nuclei would contain no hydrogen, if the suggested structure be correct.

The authors regard the H atom that is expelled from the nucleus as not incorporated in it but as being a satellite. The production of backward-moving atoms from aluminium may arise thus. The alpha-particle may strike the H atom at such a point in its orbit around the nucleus as to drive it toward the nucleus about which it describes a hyperbolic path, just as a comet approaches the sun, passes it and then moves back toward the regions of space where it formerly was. Only about two alpha-particles in a million are able to liberate swift H atoms. , G. F. S.

Reduction of Ferric Salts by Mercury. LE ROY W. MCCAY and WILLIAM T. ANDERSON, JR., of Princeton University (*Jour. Am. Chem. Soc.*, 1921, xliii, 2372–2378), find that, when metallic mercury is shaken with solutions of ferric chloride in either the presence or the absence of free acid, the ferric iron is rapidly and completely reduced to the ferrous state. The same phenomenon occurs with solutions of ferric sulphate, if a small amount of either free hydrochloric acid or an alkali chloride be present. Titanic acid is not reduced under these conditions. This procedure may be used to reduce ferric salts prior to the volumetric determination of iron by titration with either potassium permanganate or potassium dichromate. J. S. H.

Subsalts of Bismuth. HENRY GEORGE DENHAM, of the University of Queensland (*Jour. Am. Chem. Soc.*, 1921, xliii, 2367–2371), has prepared a suboxide of bismuth BiO and certain compounds of bismuth in which that metal likewise is bivalent. The suboxide is obtained by heating basic bismuthic oxalate under reduced pressure for a period of six to eight hours at a temperature of 250° to 260° C. When the suboxide is treated with methyl iodide at a temperature of 260° to 262° C., several products are formed: (1) Bismuth suboxyiodide, $2BiI_2.3BiO$, a non-volatile, brick-red solid; (2) bismuth subiodide, BiI_2, a red, volatile solid which crystallizes in the orthorhombic system, and (3) a pale yellow distillate which apparently contains bismuth dimethyl, $Bi(CH_3)_2$; this compound readily oxidizes to a strongly reducing substance, possibly dimethoxy bismuth, $Bi(OCH_3)_2$.

J. S. H.

Notes on the Method of Dimensions. E. BUCKINGHAM, Bureau of Standards. (*Phil. Mag.*, November, 1921.)—In speaking of this method of deriving the relations which hold between the physical properties concerned in any phenomenon the remark is made " Lord Rayleigh's numerous applications are sometimes so concisely described that the results seem rather like magic. But while a closer study of his solutions can only increase our admiration, it will certainly lead the average reader to wish for a less intuitive

and more systematic procedure for obtaining the same sort of result. Such a routine procedure is provided by the requirement of dimensional homogeneity as a general algebraic theorem, which was first established by Riabouchinski." Doctor Buckingham shows how to attack a problem by the dimensional method, for example—" Let it be required to find how the resistance R of still air to the motion of a smooth sphere depends on the speed S." In two other problems he shows how to detect the insufficiency of the original statement of the problem and after detection how to remedy the defect. And let it not be thought that this mode of treatment lends itself to recondite problems alone, for it is brought to bear on the heating of a bearing which supports a journal. The various difficulties which may be encountered are stated and appropriate procedures are given. There is so much ripened good sense in this article that it cannot be too highly commended to those having any interest in the subject, and it can scarcely fail to interest any reader equipped with the modicum of physics and mathematics necessary for an understanding.

" Dimensional equations are conventional short-hand descriptions of general relations which subsist among physical quantities of different kinds, and the distinguishing peculiarity of dimensional reasoning is that it uses the known facts of physics only in this general form. . . . As regards accuracy, it may be remarked that the results of dimensional reasoning are subject to the same limitations as those of any other theory. Theory always operates on an ideally simplified picture of reality because real phenomena are unmanageably complicated. The results obtained are not exactly true for any real phenomenon, though they may be for an ideal one; and the approximation with which a theoretical equation, however obtained, represents the actual facts, always depends on the approximation in essentials between the ideal picture and its real prototype." " What is needed for the successful use of dimensional reasoning is neither algebra nor metaphysics, but only practice and a very modest portion of that physical common sense which the late Lord Rayleigh exhibited in so eminent a degree."

G. F. S.

Diffusion of Solid Lead into Itself. J. GRÓH and G. v. HEVESY. (*Ann. d. Phys.*, No. 11, 1921.)—These Budapest investigators last year published an interesting application of isotopes. Just as others had used colors or electrical potentials or indices of refraction to reveal the progress of diffusion, so they, desiring to study the diffusion of liquid lead into itself, came upon the happy thought of making one part of the lead radio-active by the addition of thorium B, an isotope of lead. As this portion of the lead diffused into the other part consisting of ordinary metal its advance manifested itself by the appearance of radio-activity. They now attack the similar problem in the case of lead in the solid state.

The former indicator, thorium B, must be ruled out because in

10.6 hours one-half of it is transformed and the length of the experiments with solid lead will last months rather than hours. As active material to serve as an indicator lead from Joachimsthal (that locality so often mentioned in the early literature of radio-activity and even more deserving of fame in America for having made the word " dollar " possible) was selected. It is a mixture of ordinary lead, uranium lead and radium D, of which the last alone is radio-active. A cylinder of lead and a similar one of lead with radio-active content were melted together at the surface of contact. For more than a year the compound cylinder was kept at a temperature of 280° C., 46° below the melting point of the metal. At the end of this period it was impossible to detect any diffusion of the active lead into the other end of the cylinder. Twenty-five years ago Roberts-Austen studied the diffusion of solid gold into lead, and, strange to say, obtained a coefficient of diffusion about 300 times as large as the upper limit of that quantity for lead into lead, as fixed by the negative result in view of the conditions of the experiment. Now why should gold molecules be able to work their way into lead at a faster rate than lead molecules themselves can penetrate? The suggestion is made that when gold goes into lead it breaks up to some extent the crystalline structure, thus facilitating the entrance of subsequent gold molecules, while a lead molecule leaves this framework unimpaired.

G. F. S.

A Study of the Ultra-violet End of the Solar Spectrum. CH. FABRY and H. BUISSON. (*Jour. de Phys. et le Radium,* July, 1921.) —The ultra-violet end of the solar spectrum rapidly diminishes in intensity from the wave-length 3000 angstrom units downward and no radiation at all is observable beyond 2900 units. As the sun approaches the horizon and its light must pass through a thicker stratum of atmosphere, the smallest wave-length that can be detected moves progressively toward the longer wave-lengths. This indicates that absorption by the earth's atmosphere plays a preponderating rôle in the reduction of intensity of the ultra-violet radiation. Ozone has been advanced as the substance capable of producing such absorption. It is definitely known that this gas is responsible for certain absorption bands in the region of 3300 units which occur in the light of the sun and of the stars. In the entire absence of quantitative measurements of intensity in the ultra-violet the attribution of the absorption effect to ozone has not rested on a very secure basis. The French investigators began by studying the absorption of radiation by ozone. The results were published in 1913. Then came the war during which the scientists of France, turning from academic pursuits, gave themselves to their country in order to help in saving it from the invaders. Now they have resumed their normal work and have studied the absorption of the ultra-violet by the earth's atmosphere. A comparison of this with the previous results obtained for ozone—a comparison made wave-length by wave-length—shows that a layer of ozone about

three millimetres deep at atmospheric pressure would be adequate to account, both quantitatively and qualitatively, for the observed absorption in the earth's atmosphere. A determination of the thickness of this layer from day to day shows that it varies through a range of 17 per cent. Where is this ozone located? Not near the earth, because Strutt has measured the absorption of a certain ray by 6½ km. of air near the earth and found it much less than would have been the case were the above stated quantity of ozone uniformly distributed through the atmosphere. It must then be in the higher regions of the atmosphere that the absorbing ozone exists. It may well be that there the radiation from the sun of wave-length shorter than 2000 units transforms part of the oxygen into ozone. Such radiation from a terrestrial source certainly does this. It is suggested that the variation of the solar constant, proved to exist by Abbot, may account for the changes in the quantity of ozone in the atmosphere.

From a knowledge of the absorption coefficient of the atmosphere for each wave-length the investigators are able to calculate the intensity of the ray outside of the earth's atmosphere. No systematic change of intensity depending on wave-length manifests itself. This indicates that it is not absorption by the sun's atmosphere that sets a limit to the spectrum—a conclusion confirmed by a comparison of the light from the centre of the sun with that from the edge. The effectiveness of the earth's own atmosphere in absorbing light is such that only a millionth of the energy possessed by a short wavelength at the upper confines of the atmosphere finally reaches the earth.

                                                         G. F. S.

An Interferometer for Testing Camera Lenses. F. TWYMAN. (*Phil. Mag.*, November, 1921.)—The instrument in its general outlines is based on the Michelson interferometer. " The apparatus measures the degree to which the wave-front, impressed by the lens on light from a distant point source, differs from a spherical wavefront. The interference fringes form a contour map of the wavefront with reference to a sphere." " If the observer be given for test a photographic lens he can within one hour hand the lens back with a record and photographic plate affording the following information:

" a. Focal length of the lens correct to 0.001 inch for the green and violet rays.

" b. Complete aberrations (including distortion, and the chromatic variations of aberration) for axial pencils and for five obliquities."

                                                         G. F. S.

The November, 1921, issue of the *Philosophical Magazine* is interesting from the point of view of the geographical distribution of the authors of the contributions. In all twenty-six papers are

printed. Prof. Nihal Karan Sethi, of the Benares Hindu University, and, jointly, C. V. Raman and K. Seshagiri Rao, and, again jointly, C. V. Raman and Goverdhan Lal Datta, of the University of Calcutta, present papers in the field of optics, while from A. L. Narayan, Maharajah's College, Vizianagaram, Madras, comes a paper "On Sounds of Splashes." There is at least one paper from Wales, and one from Oxford, while Cambridge contributes a larger number. London and Manchester are represented. R. W. Wood, of Johns Hopkins, L. T. More, University of Cincinnati, E. P. Adams, of Princeton, and E. Buckingham, Bureau of Standards, form the contingent from the United States.

G. F. S.

Researches on Vagabond Currents. J. CHAPPIUS and HUBERT-DESPREZ. (*Comptes Rendus*, Nov. 14, 1921.)—The currents referred to are such as wander from an electric generator through pipes in the ground and through the earth itself back to the generator. In a city there is likely to be a group of several such currents superimposed and flowing through the same conductors. A method of determining the sources is much needed.

When a vagabond current is made to actuate a telephone receiver a sort of frying sound is heard to which components are contributed by sudden variations in trolley currents, by changes in the speed of dynamos and also by those undulations in the current developed by direct-current dynamos which are due to the impossibility of maintaining the current unchanged from the instant a brush passes over to one segment of the commutator until it makes the next similar change. The experimenters developed a resonance arrangement by which the sound due to the undulations could be isolated from the sound complex and its frequency measured. As the latter depends on the number of revolutions per second made by the armature and on the number of segments on the armature there is something individual and characteristic about it. There might, however, be several dynamos emitting undulations of the same period. How shall the very " fons et origo malorum " be selected from several possible contributing dynamos? This was accomplished by connecting a three-electrode vacuum tube to the dynamo circuit in such manner that vibrations caused by the voice or by whistling could be superimposed on the current from the generator. If a stray current was found to give in the telephone receiver these added sounds, its source was at once known beyond question.

G. F. S.

Sea Casualties and Loss of Life.—A paper on this subject was presented lately before the Northeast Coast Institution of Engineers and Shipbuilders (Newcastle-on-Tyne) by Sir W. S. Abell. The question of safety at sea has been a matter of interest from the earliest times, but it is, perhaps, true that property was at first more

considered than persons. Modern practise is better. The data are collected by the study of returns from the years 1890 to 1913. It is, of course, impossible to apply the figures from the war years to a generalization. Numerous diagrams are given to show the summation of the data and the bearing of different causes of the disaster on the figures. Two disasters attended with great loss of life under exceptional conditions are included, but otherwise the several incidents were of the usual type. The two great disasters were the torpedoing of the transport *Kow Shing* in 1894 by which nearly 1200 were lost, and the sinking of the *Titanic* in 1912, whereby 825 passengers and 673 of the crew were drowned. These two incidents do not materially affect the percentage of loss of the crew, but do increase a good deal the percentage of passenger loss. The following classification on the basis of 100 is given as the approximate results of the study of the several circumstances that may cause loss:

Weather conditions	37
Errors by personnel	25
Defects of ship or machinery	17
Fire	7
Miscellaneous	15

The loss of life in stranded vessels is much greater than when the ship founders on the deep sea.

Assuming that 1,000,000 are carried per year, it seems that only by absolute perfection in the ship itself will it be possible to bring the loss of life down to seventy per year. It is pointed out that the risks of land travel are greater than those by sea. Though the numbers of deaths from most methods of land travel have diminished in recent years, the enormous increase in automobile casualties has maintained the loss of life at the 1906 figure.   H. L.

THE APPLICATION OF THE FUNDAMENTAL KNOWLEDGE OF PORTLAND CEMENT TO ITS MANUFACTURE AND USE.*

BY

P. H. BATES, A.B., B.S.

Chief, Structural and Miscellaneous Materials Division, Bureau of Standards, Washington, D. C.

Too frequently the development of Portland cement is considered to have been solely a matter of plant routine. The fact that hydraulic limes, from which Portland cement was developed and which contained those constituents that it does, were first produced as a result of investigation is generally lost sight of. However the original producers of hydraulic cements brought forward their under-burned cement as a result of research, which showed them that lime must be burned with silicious or clayey material in order to give a true hydraulic cement.

The credit for the first original research belongs to Smeaton, who wished "to have a cement, the most perfect that was possible, to resist the extreme violence of the sea" in order to build the Eddystone Lighthouse about 1756. He therefore "resolved to take every opportunity in the evenings and intervals of my attendance on the work-yard, mould-room, etc., to go through a

---

* Presented at the Stated Meeting of the Institute held Wednesday evening, December 21, 1921.

complete set of experiments on cement, so far as it concerned the subject I had in mind . . . . Having now found a species of materials, and a method of compounding them very competent to our purpose . . . . I was very desirous to get some light into some of the sensible qualities, that might probably occasion the difference, or at least become a mark of distinction. I therefore applied to my friend Mr. Cookworthy, whom I had found at all times ready to afford assistance . . . . He taught me how to analyze limestone." He then goes on to show how he made his analyses and found that " the most pure limestone was not the best for making mortar, especially for building in water . . . . even the Dorking lime, much esteemed for these uses at London, and in the country round about, is plainly nothing but a species of chalk, impregnated with clay, of which it makes one full seventeenth part of the original weight." We can add that in this country, the Portland cement industry had its inception in a region (the Lehigh Valley District) where limestone " impregnated with clay " occurs in great abundance.

The product made by Smeaton was not that now known as Portland cement, but what is known as hydraulic lime. Moreover the former name did not appear until about 1824, when Joseph Aspdin, a bricklayer of Leeds, took out a patent for making a cement from limestone and clay which was called Portland cement because of the resemblance of the set product to the stone quarried at Portland, England. Between this period and that of Smeaton, several cements had been produced, all as a result of investigation which showed the necessity of the presence of impurities in the limestone. The most notable of these investigators was L. J. Vicat, whose work entitles him to be " justly considered as the creator of the industry," according to such a recognized authority as Henry Le Chatelier.

However, none of these actually produced commercially what we now consider as Portland cement. The greater part of their product consisted of a soft burned material which corresponded to what we now know as Roman, Natural or Rosendale cement or hydraulic lime. If perchance some was "over-burned" so that a clinker was unintentionally produced, it was generally discarded and only the soft burned product went into use. The composition also had not developed into that used to-day, a much lower limed raw mixture being in use. Gradually the value of the hard

burned product was recognized, and with its recognition increased the desire to produce it, until about 1875 (in this country and possibly twenty years earlier abroad) we find Portland cement as we now have it—a commercial product.

From Smeaton to Vicat the investigative work was actively pursued in Sweden by Bergmann, in France by de Morveau and Collet-Descotels, and in Switzerland by Saussure. The first of the above proposed a theory which remained generally accepted until Vicat's work—a period of almost fifty years. This theory of Bergmann is of interest particularly as showing the methods employed in the research and to what erroneous conclusions they lead. Having found by chemical analysis alone, that certain hydraulic limes of Lena contained considerable amounts of manganese, he attributed the hydraulic properties of the material to this constituent. His illustrious reputation caused this theory to be generally accepted, and notwithstanding that de Morveau could find manganese in only one hydraulic lime of France, he refrained from contradicting Bergmann. Saussure in Switzerland found the same condition but again refrained from contradicting him, though he did maintain that clay could replace manganese, but would be inferior. The value of the chemical analyses so erroneously interpreted at that time remains to-day entirely too highly esteemed, and it is with difficulty that its proper place is recognized both in investigative and commercial usage at this late date.

Vicat's work stands out prominently in every respect. It was not undertaken to develop a product, as had been so much of the previous work, but was almost solely for the purpose of determining what a material was and what in the material caused it to react as it did with water. While he busied himself almost entirely with hydraulic limes, his method of working and reasoning was such as to cause it to be followed for years. His intense interest in these limes, especially when mixed with puzzolana, led him to materially underestimate the value of the Roman cements —the nearest approach to Portland cements at that time.

Following Vicat we have a number of investigations being carried on in France and Germany. The work in England was almost entirely dropped, but plant development rapidly pursued. Germany had taken up the investigation of hydraulic limes and Roman cements actively, the first investigator, John, being contemporaneous with Vicat. He was followed by Fuchs, Sefstroms,

Pettenkofer, Winkler, Feichtenger, Zulkowsky, Heldt, and Michaelis. Some of these produced in their studies Portland cement such as we have now, though the majority confined their attention to low burned products of either the high lime (hydraulic cement) or the low burned (Roman cement) type. One observation of Sefstroms is of particular interest. In his noting about 1827 the dusting of compositions corresponding to the formula $2CaO\ SiO_2$ we have the first noting of what was but a few years ago shown by the American investigators of the Geophysical Laboratory to be the inversion of the beta form to the gamma form of this compound. In France the investigations of Vicat were continued by Berthier, Rivot, Fraemy, Landrein, and Merceron.[1]

The advances either in Germany or France are not very striking when compared with that made by Vicat. Various formulæ were assigned to the different constituents, as a result of chemical analysis of either existing cements or of the set product, or of the products resulting from leaching the cements by either water or other solutions. The value of the constituents thought to be present, as hydraulic or cementing products, was hazarded as a result of these analyses, but there was a lack of general acceptance of these theories due to an appreciation of the lack of proper approach to the problem.

Le Chatelier by his work published in 1887 brought prominently into usage the microscope first used in cement investigation by Winkler. By using the microscope to examine the products produced by burning definite mixtures, by means of chemical analyses of these and of commercial products, he announced the composition of Portland cement to be a tricalcium silicate, tricalcium aluminate, "calcium ferrate" and "multiple silicates." These conclusions remained partly confirmed but never adequately disproven by such eminent foreign investigators as Michaelis, Oddo, Tornebohn, Rebuffet, Rohland, or our own Newberry and

---

[1] It is not thought advisable in the space of a short paper to give the many references where the work of the above investigators can be found. These, together with a valuation of the work of each, may be found in the four following publications: "Experimental Researches on the Constituents of Hydraulic Mortars," Le Chatelier, translated by J. L. Mack, published by McGraw-Hill; "Cement," Betram Blount, published by Longmans-Green & Co., London; "Der Portland Zement," Schmidt, published by Konrad Wittwer, Stuttgart; "Die Chemie der hydraulischen Bendemittel," Kuhl and Knothe, published by S. Hirzel, Leipzig.

Richardson, until the eminent work of the investigators, especially Rankin, of the Geophysical Laboratory of the Carnegie Institution. It should be stated as a special credit to Le Chatelier, that while even the latter at first did not confirm the existence of the tricalcium silicate yet the final work of Rankin gave it the prominent place assigned to it by Le Chatelier. The very excellent work of Newberry must also be given a prominent place on account of the wide acceptance by the cement manufacturers of the ratio suggested by him as a means of controlling the composition.

The publications of the Geophysical Laboratory, in connection with their investigation of the system lime-silica-alumina, have given us a true insight into the constitution of Portland cement. Applying the phase rule by means of the best experimental methods of physical chemical attack, coupled with an extensive use of the petrographic microscope, they have shown that well-burned clinker contains tricalcium silicate, dicalcium silicate, tricalcium aluminate, and a certain amount of slag or glass high in oxide of iron.[2]

It is difficult to appreciate the enormous amount of experimental work done in this investigation, but some slight realization of it may be gained from the fact that "some 7000 heat treatments and subsequent optical examinations of the product" were made. The very stupendousness of the work precludes its duplication within any reasonable period, but at the same time the correctness of the conclusions has been checked many times in the course of work which included not only those compositions which are included in Portland cement but also all those of the entire ternary system. Here and abroad generally the results have been accepted as conclusive. In Germany the prejudice against accepting the existence of tricalcium silicate so strongly insisted upon by Le Chatelier, continues, and several poorly designed and poorly carried out investigations have been made to prove that this is a ternary compound containing a small amount of alumina.

In order to apply on a large scale certain of the generalizations made in some of the first papers of the Geophysical Laboratory the Bureau of Standards erected at its Pittsburgh branch an experimental cement plant during 1911. This was equipped with complete grinding apparatus and a 2′ x 20′ rotary natural gas kiln.

[2] "Portland Cement," Rankin, JOURNAL OF THE FRANKLIN INSTITUTE, vol. 181, 747.

A series of burns was outlined in which a wide variation in the composition was maintained. After burning, a complete chemical and petrographic analysis was made. The clinker was then ground and from the resulting cement the different small physical test pieces were made, as well as concrete test pieces in the form of 6 x 12 cylinders, which were broken at various periods. Such an investigation would serve to show not only how the various constituents would affect the strength, but also how the strength would be affected by variations in the amount of the constituents. Another series on a smaller scale was carried out wherein pure alumina, silica and lime were used. These latter, on account of preventing contamination from kiln linings, were not made in the rotary kiln. Also in order to secure the silicates separately a higher temperature was desired than attainable in a rotary kiln. This series would serve to show the relative setting and hardening properties of constituents uninfluenced by the presence of a second or influenced by a definite amount of a second added by mechanical mixing after separate preparation.

These investigations, presented to the public partly in Bureau of Standards' Technologic Papers Nos. 43 and 78, have not only borne out the conclusions of the Geophysical Laboratory, but have applied them to elucidating the chemistry of hardening.

The much discussed tricalcium silicate was prepared containing little more than traces of alumina. It was found to have all the setting and hardening properties of ordinary Portland cement. The dicalcium silicate of the same degree of purity was found to harden so slowly that it had no commercial value. However, if allowed to remain in contact with water for a period of from two to three weeks it gradually hardened until at the end of three or four months it had as great a strength as the tricalcium silicate or Portland cement. The tricalcium aluminate when pure hydrated almost instantly with a marked evolution of heat and never secured a true set or hardening.

These conclusions naturally give rise to certain questions. If the tricalcium silicate has all the properties of Portland cement, why not manufacture it alone in the absence of the very slow setting dicalcium silicate or the non-hardening tricalcium aluminate? Has either the dicalcium silicate or tricalcium aluminate any essential functions either in the process of manufacture or usage? If the tricalcium aluminate alone reacts almost instantly with water

and does not set, how are these properties masked in the finished cement?

These questions require a study particularly of the work of the Geophysical Laboratory. The latter has shown that the tricalcium silicate starts to form from the oxides at 1400° C. through the intermediate formation of the dicalcium silicate. This combines at higher temperatures, or with a longer heating with more lime, to form the tricalcium silicate. This disintegrates at about 1920° to the dicalcium compound and free lime. But the most striking feature in regard to the tricalcium silicate is the fact that " it is found as a primary phase only within the ternary system." Hence the possibility of obtaining this pure at commercially obtainable temperatures in quantities at a cost to compete with the price of Portland cement is out of the question. The work of this Bureau does not show that such a pure product would have cementing qualities which would justify much greater cost than Portland cement. The possibility of using a cheaper material than alumina to form a ternary system is not likely, as by the use of clay, especially widely distributed and very cheap, two of the three oxides desired are readily obtained. The Bureau in its work used either the oxide of boron or chromium, neither of which is sufficiently cheap to compete with alumina. In this work not one but six successive burnings were required to produce the compound containing less than 2 per cent. of free lime. Why it would not be possible to produce it on a commercial scale under present methods is hence quite evident.

The dicalcium silicate forms much more readily than the tricalcium compound, especially in the presence of a third oxide, as alumina, and is not decomposable at its melting point. Mixtures of silica and lime such that this compound would form react rapidly and at commercially obtainable temperatures. The presence of alumina in small amounts decreases the temperature required to bring about the formation of the compound. This compound after a month or more of its slower hydration has a strength approximately equal to the higher lime compound, but its water of hydration is only about one-third the latter. It is the more stable product of the two silicates in respect to water and hence would be the more desirable to resist weathering so far as solubility is concerned, if it were not for the fact that after setting it has a very sandy structure and is not free of voids. It hence

contains cavities in which water may freeze or salts crystallize, and in this respect does not offer a good medium for weathering. The tricalcium aluminate by its rapid hydration assists in breaking up the granules of finely ground clinker and also in increasing to a slight degree the hydrating of the silicates. Any free lime existing in the clinker or that formed by the hydrating of the silicates, in the presence of gypsum added for regulating the set, very markedly reduced the reaction of the aluminate with water and actually gives this compound some cementing qualities. In the previous paragraph attention was called to the slow rate of hydration of the dicalcium silicate. The slow hydration noted and the open sandy appearance both require the presence of another material which will hydrate rapidly and to a denser mass. These two properties are furnished in a striking manner by the tricalcium silicate. It was found that mechanical mixtures of these two silicates in equal amounts produced a cement which had the desired density of Portland cement after hardening, and at late periods a very comparable strength. Later examinations of commercial clinker showed that in these mixtures the amount of high limed compound was low and that with mixtures of the correct proportion a product equal to Portland cement would doubtlessly have been obtained.

Before leaving the subject of pure compounds it would be desirable to call attention to certain of their properties which have been noted by different investigators, but in certain cases not fully explained. The presence of uncombined lime in these and in Portland cement has been a matter of much discussion. Thus, in the tricalcium silicate used in part of this investigation as much as 2 per cent. of free lime was noted, but the silicate was sound according to the usual test—because the test piece had attained a strength before test in excess of the disruptive force developed by the hydrating of the lime during the test. The dicalcium silicate hardens so slowly that it is likely that it would have to be aged a month before it would have sufficient strength to be sound in the presence of the same amount of lime. The dusting of dicalcium silicate and of low burned or too high silica Portland cement is a commonly noted phenomenon. This is due to the inversion of the beta to the gamma form of the dicalcium silicate with an increase in volume of about 10 per cent. Whether this inversion may be delayed to a late period, as for instance after the cement has gone

into a concrete, with consequent destruction of the concrete, has been discussed repeatedly. The Bureau has made a number of cements in which the clinker dusted slowly (it is surprising how much many clinkers will dust in the course of three or four years). But it has not been able to note any destruction of set cement in any form in specimens made of these cements. Disintegrated concretes made of commercial cements have been examined for the same purpose, and none of the gamma form noted. A number of investigators have questioned the possibility of hydration of the dicalcium compound. This has been due, however, to their not observing the phenomenon of its hydration over a sufficiently extended period. Test pieces made of it cannot be handled at the end of a week without breaking. At the end of a year they will have attained strength approximately equal to that of Portland cement, but will have acquired only about 5 per cent. water of hydration. Crystals of hydrated lime are plentiful in the specimens, showing the breaking up of the compound to a silicate of lower lime content. The tricalcium silicate will have acquired at the end of a year more than twice the water of hydration of the dicalcium compound. The former compound also gives off lime during its hydration. Many investigators have noted that the tricalcium aluminate sets and hardens. However this is another compound which decomposes at the melting point, giving off lime. If the two oxides, in the proportions to form $3CaO \cdot Al_2O_3$, are heated to the point of vitrification, $5CaO \cdot 3Al_2O_3$ and CaO result. The true tricalcium aluminate free of lime can be obtained only by heating the oxides for a long period at a temperature of about $100°$ below that required for vitrification (about $1450°$, dissociates at $1535°$). This mixture of $5CaO \cdot 3Al_2O_3$ and CaO sets and hardens rapidly and could be used as a very quick setting cement. It is this mixture which has been the subject of investigation, as it and not the true tricalcium compound has been obtained in by far the majority of cases. Chemical analyses will not determine whether the compond $3CaO \cdot Al_2O_3$ is formed. The microscope is essential to determine the free lime.

The work which the Bureau carried out in its rotary kiln has been of particular value in showing the amounts of the several constituents that may be obtained in general manufacturing practice, and how these affect the product as a cementing agent. In this work the composition of approximately 50 cements (each

made after burning a half ton of raw material) was varied so that the tricalcium silicate content ranged from a trace to approximately 51 per cent. The dicalcium silicate varied from 12 to 74 per cent., and the tricalcium aluminate from 14 to 33 per cent. These figures were obtained by petrographic examination of thin sections of clinker. The data have been studied in a great many ways—by the plotting of strength at various periods against the ratios suggested by Le Chatelier, Michaelis, Newberry and others, as obtained from the chemical analyses; by plotting the strength against the amount of the constituents as obtained by petrographic analyses, and by plotting the strength against molecular formula, calculated both

TABLE I.

Showing the effect of the di- and tricalcium silicates upon the strength, in pounds per sq. inch, at different ages, of cements in a 1:1.5:4.5 gravel concrete. Arranged in groups depending upon the SiO_2-Al_2O_3 ratio.

Average $\dfrac{SiO_2}{Al_2O_3}$	1.25	1.75	2.25	2.75	3.25	3.75	4.25	4.75
3 CaO SiO_2	36.3	22.0	30.2	26.1	16.2	31.4	21.1	7.6
3 CaO SiO_2 plus 2 CaO SiO_2	54.8	57.5	65.1	43.0	71.5	72.6	68.9	67.0
Strength at 4 weeks ..	1660	1205	1655	1315	960	1560	1560	570
Strength at 1.5 yrs. ...	2375	2265	2700	3110	2670	3215	3240	2705
Strength at 5 years ..	2650	3020	2960	3290	3170	3470	3610	3305

from the chemical and petrographic analyses. The majority of these show but little of interest, while others bring out striking facts. But the most striking feature of all is that composition or constitution are meaningless so far as predicting the quality of a cement unless the period of hardening is considered. This can be realized from what has been stated before in regard to the speed of hardening of the several compounds. Table I, presenting certain of the data, will show this fact, and at the same time illustrate one of the methods of presenting the data in such a tabular form as will show a comparison of one of the common ratios with changes in constitution and with strengths produced in concrete at certain ages.

The data in Table I have been arranged by placing each of about 50 cements, all made at the Bureau, in one of several

groups depending upon whether the silica-alumina ratio lay between 1.00 and 1.50; 1.50 and 2.00; 2.00 and 2.50, etc. In the table the first group above is given in the second column under the ratio 1.25, the second under the ratio 1.75, etc. These ratios were obtained from the analyses of the clinker by reducing these by calculation to the 5 compounds—silica, alumina, iron oxide, lime and magnesia as equaling 100 per cent. The amounts of the two silicates were obtained from petrographic analyses of thin sections of the same clinker. In the table the amount of either constituent is the average of all the cements in the group. The strength was the average of the 6 x 12 concrete cylinders for all the cements in the group.

The difficulty of deriving any conclusions from such a tabula-

$\dfrac{SiO_2}{Al_2O_3}$	$\dfrac{CaO}{SiO_2+Al_2O_3}$	CaO equivalent to $2.5SiO_2+1.6Al_2O_3$	CaO by analysis	$3CaOSiO_2$	$2CaOSiO_2$	Strength of 1:1.5:4.5 concrete tested at		
						4 weeks	1.5 yr.	5 yrs.
2.29	2.17	65.8	64.1	61.8	16.8	2380	3845	4510
2.71	2.26	64.9	65.1	51.5	18.0	2480	4260	4750
3.35	2.33	65.0	65.9	49.8	22.0	2700	4530	5150
1.67	2.16	64.5	64.5	29.5	25.0	1925	3130	4180

tion is immediately apparent, but the reason for the difficulty is not so evident. It is, however, due to the fact that in any group we have the tricalcium silicate ranging from a very small amount to a very large one—as for instance in the group with a ratio of 3.25 it ranges from a trace to 49.8 per cent. In other words a ratio depending upon the composition may classify as similar, cements which differ widely in their constitution. The same applies to all other ratios that have been proposed, whether they are based upon either a percentage or a molecular basis. This is further illustrated in the following tabulation of data secured from the examination of but four cements and the concrete made from them.

It is clearly evident from the above that the silica-aluminum ratio in these four cases again fails as a criterion of the value of a cement; that the lime-silica plus alumina ratio as well as the Newberry formula, shown at the top of the third column, does not predict the amounts of the constituents although for late periods

it is a fair index of the strength. The failure of the lime-silica plus alumina ratio can be readily appreciated from the wide variation in the relative amounts of silica or alumina that is possible and yet have their sum constant. The use of molecular quantities instead of percentages does not materially affect the significance of this ratio derived from several cements, although it does change the numerical value.

The Newberry formula, on account of its very wide application in plant control, was studied more closely by grouping 23 cements which did not deviate too much from normal commercial composition into three groups. In the first group the average lime content, as found by analysis, was in excess of that calculated by the Newberry formula; in the second it had approximately

CaO equivalent to $2.5SiO_2 + 1.6Al_2O_3$	CaO by analysis	$3CaOSiO_2$			$2CaO.SiO_2$	Strength of 1:1.5:4.5 concrete tested at		
		Average	Maximum	Minimum		4 weeks	1.5 yr.	5 yrs.
59.8	65.6	40.8	43.1	37.2	14.3	1865	2565	3000
65.3	64.9	38.9	51.8	23.4	26.1	2030	3435	3735
70.8	62.6	25.5	44.7	14.3	38.3	1400	2775	3210

the same value, and in the third the lime content was considerably below that derived from the formula. The above tabulation shows the results of this grouping, together with the average strength of the cements in the group and data concerning the constituents.

Again the formula apparently is of no service in predicting the constitution, but the failure is due either to differences in degree of burning or in composition. Thus the compositions of the cements showing maximum and minimum tricalcium silicate in the second group are very similar, but the one with minimum tricalcium silicate was decidedly underburned and unsound—although it had a strength of 3765 pounds per square inch in the concrete at the end of five years. In the third group the cement with the minimum tricalcium silicate was one with a high alumina content and low lime and silica, whereas the one with the maximum content was a low alumina but high lime and silica content. However, an analysis of the data from all the cements shows that this formula

is the superior of any of the ratios ever suggested. But even it cannot be used to make deductions as to the quality of a cement from the results of chemical analyses, particularly on account of the latter not showing the degree of burning.

How the petrographic analyses will predict the cementing qualities can be inferred from the above tables and discussions. It can also be grasped by a study of Figs. 1 and 2. In preparing these, the clinker has been considered as being composed of but three

FIG. 1.
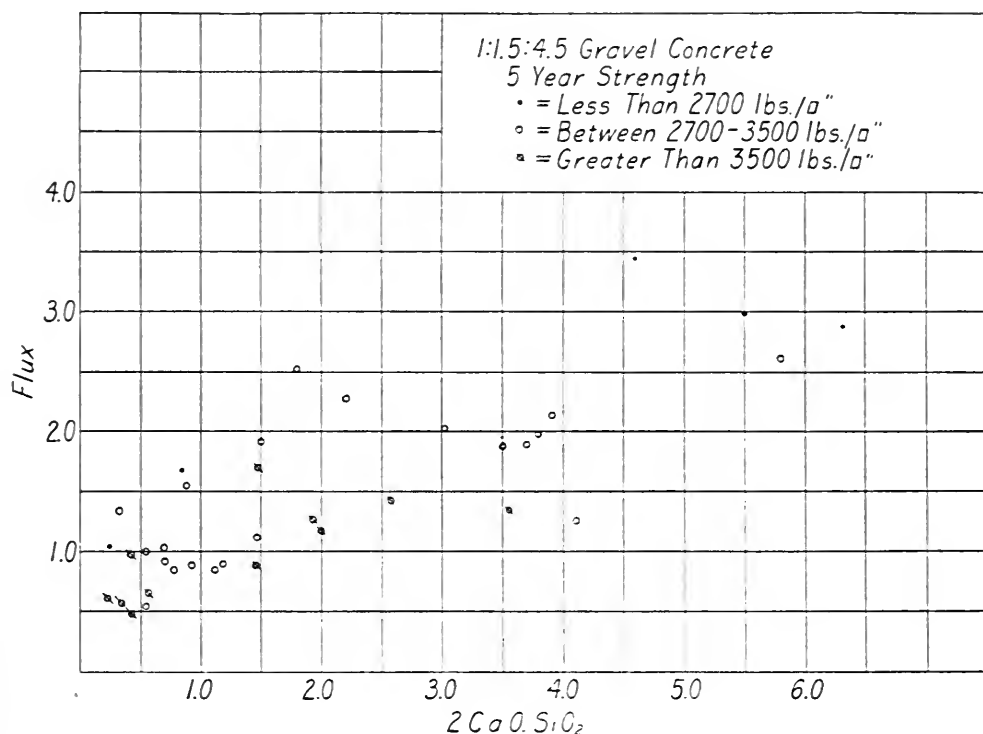
constituents—the dicalcium and tricalcium silicates and the "flux." These, as determined by the petrographic microscope, embrace all the constituents and hence equal 100 per cent. In the "flux" is embraced the tricalcium aluminate, the possible "ferrites" and the "glass" more or less colored by the iron oxide. By simply dividing in each analysis the percentage of each constituent by the per cent. of tricalcium silicate, we obtain a formula for each cement of the type—

$$3CaO.SiO_2 : x2CaO.SiO_2 : y \text{ "Flux."}$$
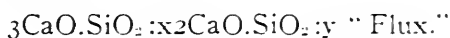
In all cases the first constituent being unity we may plot the location of the other two on ordinary rectangular coördinate paper.

These locations can then be indicated by such marks as will indicate as to which of several groups it belongs in so far as its strength at any age is concerned. This procedure has been followed in preparing Figs. 1 and 2.

From these it will be noted, as previously stated, that the effect of the tricalcium silicate at the four-week period is very marked in producing high early strengths. This is shown by the fact that those cements low in dicalcium silicate and "flux" fall in the

FIG. 2.

1:1.5:4.5 Gravel Concrete
4 Week Strength
• = Less Than 815 lbs./□"
○ = Between 970–1560 lbs./□"
⬚ = Greater Than 1650 lbs./□"

lower left hand corner of the figure, while the locations of the others are stretched out across to the upper right hand corner. The location of each cement is indicated by one of three marks depending upon the strength of the cement as indicated by the concrete specimens. In the case of the four-week specimens, the marks indicate strengths ranging from 345 pounds per square inch to 2700 pounds, while at five years the strengths range from 2110 pounds to 5150 pounds. As at the former period the maximum value is about six times the minimum, while at the latter period the maximum is but two and a half times the minimum, the effect of the dicalcium silicate in conferring strength with age is readily seen.

These figures also present the opportunity of deriving a formula for cement of best general strength qualities. They show that when the dicalcium silicate exceeds 1.5 molecular ratios the strength at four weeks will be low, though for best results this should not exceed 1.0; but if late strengths are considered then it may reach 2.0 and be of good quality. The flux should not exceed 1.0 in any case. Hence the formula would appear for early strength as

$$3CaO. SiO_2 : 2CaO. SiO_2 : \text{``Flux.''}$$
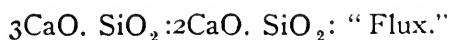
If the flux were pure tricalcium aluminate this formula would reduce to a percentage composition of 66.9 per cent. lime, 18 per cent. silica, and 15.1 per cent. alumina. Such a composition, however, would not be obtained from averaging the chemical analyses of the cements in question, neither would it represent the composition of commercial cements. Hence we have rather strong evidence that the "flux" contains silica as well as all the alumina and approximately all of the iron oxide. It indicates quite clearly, however, that the two silicates are likely present in equal molecular ratios. A mixture of the two silicates only in this ratio would give 30 per cent. silica and 70 per cent. lime. Hence the percentage of silica by 2.33 equals the percentage of lime, which is rather a close approximation to Newberry's ratio of 2.5. It is, however, very interesting to note that a purely scientific investigation, carried out entirely from the viewpoint of constitution, should confirm commercial Portland cement manufacturing practices in the use of present compositions.

It is evident that so far as early strength is concerned a cement of relatively high tricalcium silicate content is desired (see Figs. 3 and 4). Such a cement not only gives high early strengths but does not apparently lose strength with age. (It can be readily noted, however, that it does not have a high rate of strength increase with age.) Therefore the possibility of producing cements with a high content of this constituent is very attractive. The use of other fluxing or catalyzing agents than alumina have been suggested. The iron oxide occurring as an impurity in the clay and magnesia as an impurity in the limestone act in this capacity, but cannot be used to a greater extent than that now done commercially without adversely affecting the required properties. The former, in excess, gives a slow setting product and the latter in

FIG. 3.
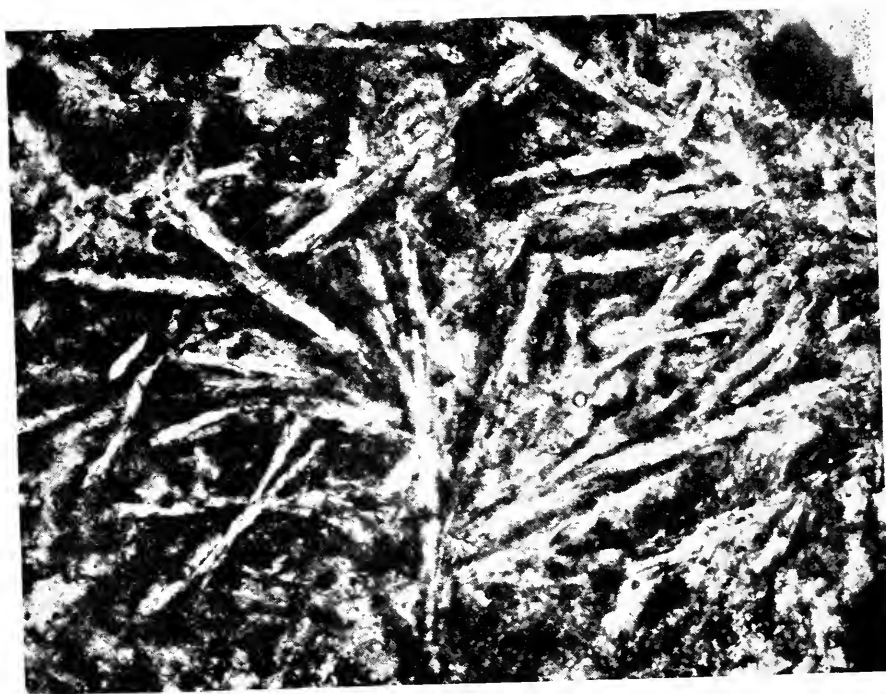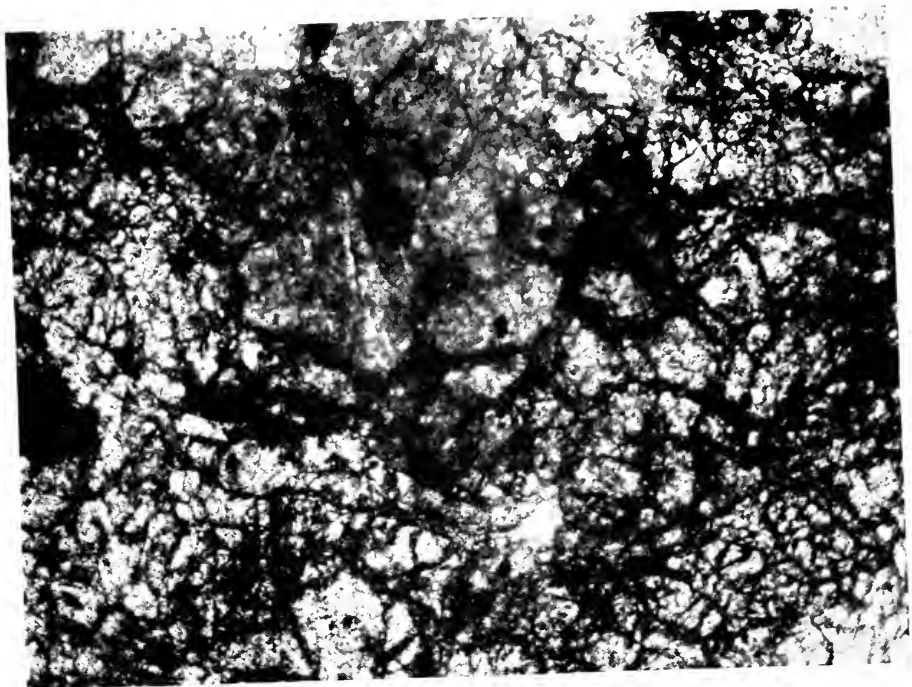
Upper.—Photomicrograph of a section of clinker of normal composition, nicols of microscope crossed. Note the large, poorly defined grains and lack of crystalline structure; contrast with lower photomicrograph of a section of clinker of approximately 17 per cent. silica, and 11 per cent. alumina content, and note large crystals of tricalcium silicate. Such a cement is not quick setting and deports itself in the kiln as one of normal composition. Magnification in both cases—135 diameters.

addition to slow hardening gives difficulties in manufacture through the formation of excessively large clinker which reduces kiln output.[3] The Bureau in its experimental plant made a series of burnings using calcium fluoride to replace some of the limestone and another in which boracic acid was used. The results were disappointing, as in both cases a slow setting and hardening product was obtained, although the lime content exclusive of magnesia was carried close to 70 per cent. However, under these conditions the cements were sound, although the test pieces had to be aged 48 hours before testing, as at earlier periods final set had not been acquired.

High tricalcium silicate can also be obtained by increasing the lime content and reducing the silica. This demands a higher temperature for burning, which in turn increases the cost of production if present procedure is followed. The possibility of an entire change of production procedure is attractive and of interest. It is well known that burning at a lower temperature for a longer period will produce the same result as burning at a high temperature for a shorter period. Hence the suggestion of trying kilns of the tunnel type instead of the rotary type. For use in such a kiln the raw material after grinding would be briquetted, placed upon cars and passed through the tunnel, a certain section of which would be heated to the desired temperature. The heated products of combustion could be directed to a waste heat boiler or to preheating the briquettes entering the kiln. This type of kiln, so far as fuel conservation is concerned is the most economical now in use and that it could be used to reach a temperature as high as that required for burning cement is evidenced by its usage for burning fire brick. Modern machine methods for making, molding and handling brick would reduce the apparent cost of this part of the procedure to a minimum. The economy of such a kiln is further realized by the fact that practically the entire section of the kiln is filled with the charge, while in the rotary kiln only a very small section is in use at any time.

Another suggested method is that of the use of admixed fuel in the raw material in the form of coke breeze, anthracite culm,

---

[3] *Technologic Paper No. 102 of the Bureau of Standards,* "The Properties of Portland Cements Having a High Magnesia Content," gives the results of a study of the effect of magnesia in cements conducted along the lines of the investigations under discussion.

Fig. 4.
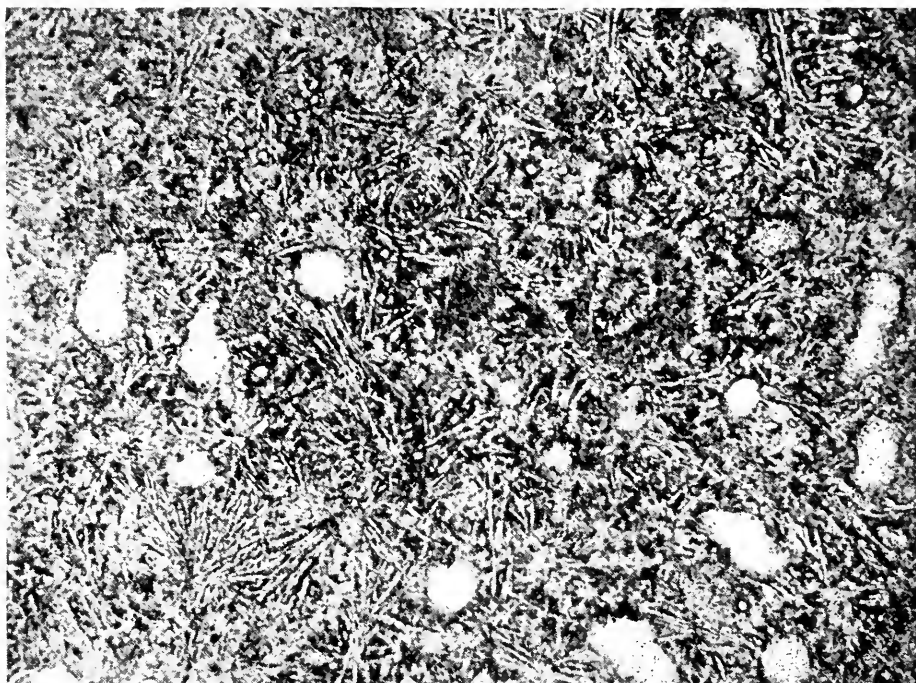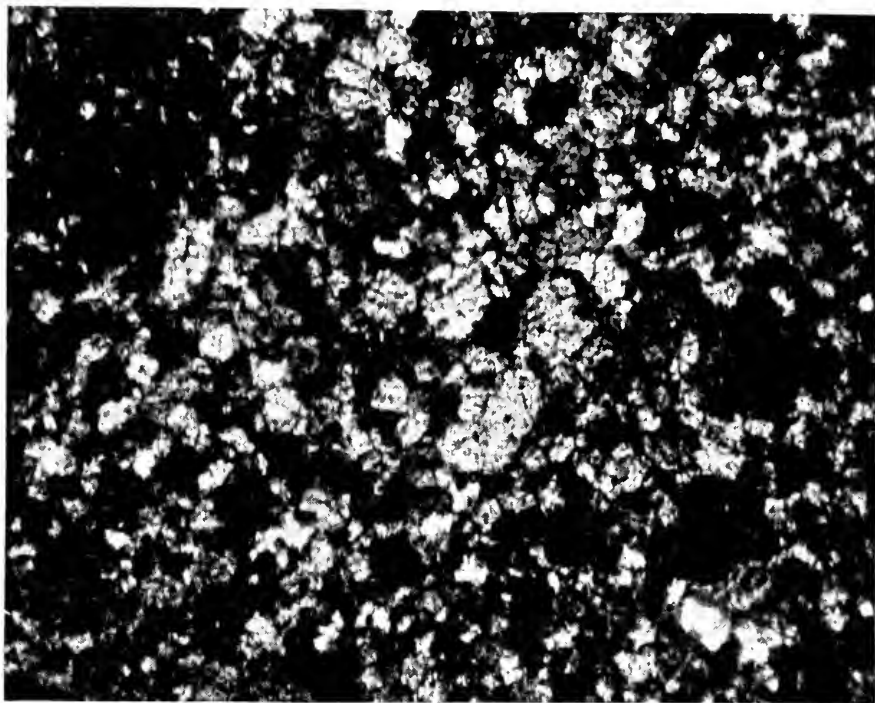
Upper.—A photomicrograph of a section of clinker of normal composition, nicols crossed, magnification 90 diameters. Lower.—Of a section of high alumina cement, magnification 40 diameters. See remarks under Fig. 3.

etc. Some preliminary work at the Bureau indicates that the combustion of the fuel in such close contact with the raw material as is brought about by this procedure materially reduces the temperature and fuel required. Further confirmatory work on a large scale is contemplated and partly under way.

The oft repeated suggestion of fusing the clinker in something like a blast furnace will not be quieted until it has been actually shown to be a success or failure. This like the previous suggestion when carried out in a modified blast furnace carries with it the use of a solid fuel in contact with the raw material. Recently considerable attention has been directed to " fused cement " being produced in an electrical furnace in France. This is not, however, Portland cement (which latter must be considered silicates of high lime content with the tricalcium aluminate as a minor constituent), but is one or both of the highly aluminous lime aluminates ($CaO.Al_2O_3$ and $3CaO.5Al_2O_3$), with a low limed silicate or silico-aluminate of lime as the minor constituent. This class has been under investigation for a number of years by the Bureau, whose recent publication, Technologic Paper No. 197, gives the results. They are indeed wonderful cements, but do not require fusing for manufacturing, but on the other hand require a source of cheap alumina, which is not available in this country. Fused Portland cements of usual composition do not appear very desirable or necessary. They would require excessive cost in burning and subsequent grinding. Also it is a matter of daily practice to secure cements free of uncombined lime in the ordinary clinkering process. Harder burning, even to the point of fusion, cannot secure more or even a different combination of the compounds, unless the lime content were increased beyond that usually used. In such a case a higher temperature would be required to complete the reaction between the dicalcium silicate and the lime, the temperature needed depending entirely upon the amount of lime present in excess of that now commercially used. On the other hand it should be borne in mind that at 1900° the tricalcium silicate decomposes into the dicalcium and free lime. At that temperature the decomposition is complete, but starts considerably lower. Hence in a fused clinker of the usual composition, rapidly cooled, free lime would be present.

At the present time there is but one standard for Portland cement, no matter into what use it ultimately goes. Is this good

practice? The answer must be in the affirmative if considered from the viewpoint of our present knowledge of cement testing. The practical cement user, however, has answered the question negatively in many cases—when he uses one or more brands in preference to others for certain classes of work or at certain periods of the year. In this connection may be cited the belief that certain brands always produce a non-dusting floor, while other brands produce a dusting floor. In all cases the various brands invariably meet the requirements of the standard. The requirements of the latter do not bring out the differences which usage has found to exist. Hence for certain uses special tests will have to be devised which will determine the desirability of any brand over another for any particular case. The question arises as to what is a particular case. Should cements for massive construction be different from those for road construction, or for interior pavement or for seawater or alkali work, or for reinforced concrete? The former does not of necessity demand high tensile or compressive strength like the latter, while for the pavement strength is of relatively minor importance when compared with non-dusting. For seawater or alkali resisting work the physical properties are relatively of minor importance when compared with the need of resistance to chemical action.

High compressive strength can be secured by a high tricalcium silicate content, a silica content of about 20 per cent., a usual alumina content and hard burning of such a raw mixture ground more finely than is usual. Such a cement, however, is brittle and of low tensile strength after an early age, hence it is not desirable for road work. It commends itself for floors but requires special skill in handling or it will dust continuously. Material changes in our present tests would have to be made to show the value of any marked changes in methods or procedure of manufacture. Earlier strength tests than seven days would be required; both a tensile and compressive test would have to be considered and a test to determine the coefficient of expansion with age. If by change in composition it can be shown that a cement more resistive to salt action can be secured it may be necessary to incorporate further chemical determinations in our specifications. The possibility of determining the quality of the cement in a concrete at a late age by an accelerated test, in other words determining its cementing qualities when it has largely hydrated, is worthy of much research.

Hence aging at higher temperatures in an atmosphere of water vapor should be a subject of much further and more logical work than heretofore.

This is truly the "Cement Age," but the development of the cement is in its infancy notwithstanding that in this country, where it has secured its widest and most daring application, it is hardly more than fifty years old. But the industry while growing old has developed too broadly physically and too narrowly mentally. After the first few years of a well-balanced development the environments furnished such strenuous physical exercise in developing a market against foreign competition and keeping up with the market once developed, that a magnificent physique was developed but mentally equipped only to keep this physique of production in condition. Recently, however, cost problems and service questions (in particular) have forced the industry to consider its mental shortcomings, and it is now engaged in overcoming these by such thought of technical matters along various lines as serve to demonstrate that it will be able to discuss and settle them in due course along well-developed scientific lines.

The Application of Anode Rays to the Investigation of Isotopes. G. P. THOMSON. (*Phil. Mag.*, November, 1921.)— The author of this paper is the son of Sir J. J. Thomson. Among British physicists there is at least one other of the second generation, Lord Rayleigh. In this connection the names Bernouilli and Berthelot will suggest themselves to the reader. Perhaps there is no better illustration of the transmission of scientific ability from father to son than in the case of R. Kohlrausch whose two sons, W. and F. Kohlrausch, both won distinction and two of whose granddaughters were wedded to men of scientific attainments, W. Hallwachs in Leipzic and Professor Day in Washington.

There are four ways of getting positively charged metallic atoms in the search for isotopes by electromagnetic analysis:

1. By sending an electric discharge through a volatile compound of the metal. Aston used this method with nickel carbonyl, but it is limited in application.

2. Dempster's method of volatilizing a metal, not yet fully described.

3. Positive particles emitted by salts heated for the purpose. A very low pressure in the gas is required.

4. Anode rays given off by an anode under bombardment by gaseous ions. In this method a moderately high pressure is used.

The last method was employed in the present research. The

anode was made by packing into a quartz tube powdered graphite and a halogen salt of the metal to be examined. When the discharge passes, there is a glow on the surface of the anode and a beam comes out from the surface. A fine pencil of this beam of anode rays is separated by letting the whole fall on a tube having in it a hole only .2 mm. in diameter. The small pencil that gets through is then subjected to the simultaneous influence of magnetic and electro-static fields whereby the rectilinear ray is bent into a parabolic form from whose dimensions it is possible to calculate the atomic weight of the atoms in the ray. The form of the parabola is recorded on a photographic plate.

Lithium is found by Mr. Thomson to consist of isotopes having atomic weights of 6 and 7. The line due to the 6 constituent was " sometimes considerably stronger than would be expected from the atomic weight, 6.94." Beryllium gave no sign of having atoms of atomic weight different from 9. Calcium and strontium lay without the limit of the resolving power of the apparatus used. " It is, however, certain that one or more of the atomic weights (39, 40 and 41) were present (*i.e.,* when calcium was tried) ; and as all these are already known to exist as isotopes of other elements (39 and 40 potassium, and 40 argon), it is clear that calcium is an instance of a so-called isobar. No previous instance had been known except among the radio-active elements."

It is to be hoped that the word " isobar " in this sense will be replaced by some other term, since isobar already has quite a different meaning in meteorology.

G. F. S.

Selenium and Tellurium Compounds as Intensifiers of Gasolin. (*Am. Chem. Soc. News Serv.*)—Authoritative reports from the laboratories of the General Motors Company give information that by the employment of selenium oxychloride or diethyl telluride the efficiency of a given amount of gasolin can be doubled. The data have been obtained by Midgley and Boyd. The tellurium compound was the most efficient, and is especially advantageous in eliminating the " knock " which is developed when a motor is laboring on a grade. Victor Lenher states that if only one hundred of one per cent. should be used in gasolin, the amount of tellurium required in the present use of gasolin in the United States will be 1500 tons. In 1920 it was ascertained that without further plant equipment the country could reduce only a little over sixty short tons. It will be necessary to find new sources of tellurium and also of selenium if these materials are to be extensively employed. A very important point will be the sanitary problems, which apparently have not yet been considered. Selenium and tellurium compounds are mostly quite poisonous.

H. L.

GASOLINE FROM OIL SHALE.*

BY

RALPH H. McKEE.

Professor of Chemical Engineering, Columbia University, New York City.

PROBABLY the first thing that I should do is to define my terms. All of you have a general idea of what gasoline is, and yet you might have some difficulty in defining it in a way which would be altogether clear. For the present need gasoline may be defined as a hydro-carbon distillate, generally a petroleum distillate, 90 per cent. of which boils below 374° F., and all of which boils below 437° F. It has a density of less than 50° Be. To be commercial gasoline it must, in addition, have but slight color and be free from certain types of impurities.

Oil shale is a type of shale occurring in considerable quantities in various parts of this country and also in many other parts of the world. On heating this it gives a petroleum from which a motor spirit similar to ordinary gasoline can be obtained. In passing, I wish to call your attention to the fact that the word " petroleum " was used for shale oil for more than twenty years before the discovery of the first oil well.

In the belief that you will be interested in a brief preliminary discussion on the present day sources of gasoline and of its possible substitutes, I would like to discuss their manufacture.

Twenty years ago all the gasoline used was obtained as the light low boiling distillate from crude petroleum. This distillate which might be called crude gasoline was then chemically treated to give the refined gasoline. The chemical treatment consisted in stirring it with concentrated sulfuric acid to remove the coloring materials, ill-smelling compounds, certain substances commonly called unsaturated compounds, and small amounts of certain basic constituents. After this sulfuric acid wash, gasoline was washed with an alkali, generally caustic soda. Following this wash with alkali solution the gasoline was redistilled and a very fine quality of product resulted. It is quite easy to make a good quality gasoline from such a quality of petroleum as Pennsylvania petro-

---

* Presented at a meeting of the Section of Physics and Chemistry held Thursday, January 12, 1922.

leum, but when the Pennsylvania fields began to decrease in output and the lower quality of oils from Ohio, Canada, the Middle West and the Far West came into the market, it was found that they did not give either as large a percentage of gasoline or a product of as high a quality as had been given by the Pennsylvania oil. On the other hand, the demands for gasoline due to the growth of the automobile industry were increasing.

The effect of this change of the commercial situation was that lower grade gasolines began to come into the market. These were lower grade in that they carried some of the higher boiling kerosene fraction, some color and some of the unsaturated constituents which give a stronger odored product. Each phase of this lowering of the standard brought about distinct increases in the amount available, but even under these circumstances the demand has increased faster than the supply, and accordingly there have been attempts to use other products to supply the deficiency. These attempts have given rise to three new petroleum products, casing head gasoline, natural gas condensate and cracked gasoline, as well as substitutes quite different from petroleum products.

When a higher boiling petroleum, of the type of the low priced fuel oil or gas oil, is heated to a temperature of around 700° F., there is a decomposition of this oil with separation of carbon on the one hand and the formation of light boiling constituents of the type of gasoline and kerosene on the other hand. This process is known as the cracking of oil and the lighter of the commercial products made is known as cracked gasoline. Cracked gasoline carries up to 40 per cent. of unsaturated compounds. Formerly we considered that a gasoline carrying as much as 5 per cent. of unsaturated constituents was not desirable or available for use in an explosive engine. To-day much of the gasoline on the market is a mixture of cracked gasoline carrying 40 per cent., with straight distillate gasoline of low unsaturated content. I do not know what your local situation is here in Philadelphia, but in New York it is not uncommon to have gasoline put into your car carrying 20 per cent. unsaturated constituents. This unsaturated product means that you have a gasoline which on standing and in contact with the air becomes colored and after a time even separates a small amount of brown tar-like deposit. This red-brown sample was formerly a water-white cracked gasoline of 30 per cent. unsaturates. It also

has a more unpleasant odor than the saturated straight distilled gasoline. On the other hand, may I inquire who of you purchases gasoline as a perfume or on its looks?

I should add that the automobile of a few years ago would not run well on the present day gasoline. It is certain that the gasoline on the market is destined to grow in its content of unsaturated compounds, and we must look to the engine designer to at least keep up and even with the changes in the type of fuel available.

There are several schemes which have been used on a large scale for making cracked gasoline. Of these the one which has been used on the largest scale is that of Dr. W. M. Burton, now President of the Standard Oil Company of Indiana. This is the process now being used by various Standard Oil companies and by which they make approximately two million gallons of gasoline a day. Burton starts, as do all other cracking schemes, with a cheap petroleum residual, preferably one of the Pennsylvania or mid-continent types. The particular point in which his process is distinctive is that he heats under a pressure of about 75 pounds, and does not relieve this pressure until after the vapors have passed through the condenser. Heating of the oil is accomplished in a steel still tank by a fire placed directy beneath it. The temperature varies during the process, but averages perhaps 700° F.

Any scheme of cracking is handicapped by the deposition of coke on the bottom and sides of the still. Burton's process suffers severely from this trouble. The original patent claims that the process gives a product free from unsaturated compounds. However, the products at present made do carry a considerable percentage of unsaturated material. The method is fairly cheap to operate but suffers, as before mentioned, from heavy flinty carbon deposits, high deterioration of stills, the dangers to operators, and also because the products formed are too unsaturated to be of the highest grade.

It may interest you to know that this development of oil cracking is to be recognized to-morrow night (January 13, 1922) in New York by the bestowal on Doctor Burton of the Perkin Medal by the American Section of the Society of Chemical Industry. The Perkin Medal is given for high attainment in the industrial application of chemistry.

Other workers have attempted to get away from the troubles of the Burton process, in particular the heavy carbon separation

and unsaturated character of the product. Doctor Rittman while a graduate student at Columbia University developed a process in which the cracking is carried out in the vapor phase instead of as a liquid. His apparatus consists of externally heated vertical pipes through which the vapors are passed under pressure. The process is one in which a pressure of 300 pounds may be used. A temperature of about 700° F. is used. By reason of the reaction being in the gaseous stage instead of liquid, the amount of carbon deposited is small, the products, however, like those of Burton, are partially unsaturated.

The third process which has been carried out in commercial plants is that of McAfee. Doctor McAfee, like Doctor Rittman, is also a graduate of Columbia. McAfee avoids the use of pressure and obtains a sweet smelling, strictly saturated gasoline. This he accomplishes by a chemical reaction of quite different type from that of Burton or Rittman. He works at ordinary pressure and at quite moderate temperatures, say 500° F. He heats the oil to be cracked with a few per cent. of its weight of aluminium chloride. This chemical, aluminium chloride, reacts with the oil to give a coke-like carbon and low boiling hydro-carbons of the type designed for motor fuel. The one handicap has been that it has not proved possible economically to recover the aluminium chloride for reuse, and the selling price of gasoline has not been high enough to permit the throwing away of the chemical after one use.

Many an oil well gives at the same time considerable amounts of gas as well as oil. If this gas is examined it is found to be formed in part by the evaporation of the same volatile constituents as are present in the liquid petroleum. If we condense the low boiling liquids from this gas we will obtain a very volatile gasoline. Gasoline obtained from the gas coming from the top of the casing of an oil well is called in the industry " casing head gasoline." There are several methods of condensing this casing head gasoline. If an air compressor is taken and this used not to compress air, but to compress the gas coming off with the oil from the well it will be found that part of the gas is condensed to a liquid. This liquid when drawn off is found to be a desirable and highly volatile gasoline. In fact its volatility is so high and its density so low that it can be mixed with higher boiling constituents such as kerosene and the resulting product appear to be a gasoline of ordinary type.

Many times instead of depending on compression alone the compressed gas is bubbled through a high boiling solvent such as gas oil and the resulting solution of gasoline in the absorbent oil later distilled to recover the gasoline and absorbent oil for reuse.

In still other plants the absorption is not by means of a heavy oil but by absorbent carbon. Silica gel is a new material which promises to displace the absorbent carbon and gas oil for this purpose as it is a still better absorbent.

We have also found that many, but not all, of the natural gas wells, wells which furnish gas but no oil, carry considerable gasoline in the gas. Gas wells of West Virginia and of Pennsylvania in general are of this type. Gasoline can be recovered from these in the same way as it is recovered from the casing head gas of the oil well.

Whether recovered from the casing head gas of an oil well or from a straight gas well, the gasoline obtained is of such a character that at the present day it is most all used for blending purposes to bring the lower grade gasoline to a higher grade. The amount of this condensed gasoline available is minor as compared with the requirements of the country.

As I stated before the requirements for gasoline are increasing year by year by very considerable amounts. We, in this country, have had gasoline cheap and in comparative abundance. This has not been true the world over. We consider 40 cents a gallon high, but most of the world would welcome gasoline at 60 cents a gallon and call it cheap. Europe is using and has been using as a motor fuel for some time large amounts of benzol, obtained as a by-product from its coke and gas plants. The Scottish shale oil plants have been furnishing considerable quantities of a motor spirit from oil shale. Cuba has had a surplus of molasses; this molasses on fermentation giving alcohol, and Cuba has been making extensive use of this alcohol not only to furnish visitors from the United with a beverage, but also locally it has taken the place to a considerable extent of gasoline for automobile uses. Natal, of South Africa, has also an abundant supply of alcohol from its waste molasses. Imported gasoline is quite expensive and, accordingly, they have devised a product which goes by the name of Natalite, and which has largely taken the place of gasoline in that part of the world. This Natalite is a mixture of alcohol with about 45 per cent. of ether. In the United States we have

had but one commercial attempt to supply a gasoline substitute. This is the "alcogas" put out by the United States Industrial Chemical Company, of Baltimore, this company being a subsidiary of the United States Industrial Alcohol Company. Each of these substitutes has its advantages and disadvantages. Benzol is decidedly cheaper than gasoline in Europe, but on the other hand it is harder to start the engine than with gasoline. Shale motor spirit of Scotland often runs 60 per cent. unsaturated and, accordingly, it is strongly odored, somewhat colored and cannot be stored for any considerable time without loss of quality. The alcohol products of Cuba and Natal, particularly when mixed with ether, as in the case of Natalite, give trouble owing to their great tendency to make the engine "knock" and also some trouble due to the difficulty of obtaining them free from acetic acid. If acetic acid is present there will be corrosion of the storage tanks, tank cars and the container tanks in the automobile. This corrosion and also the "knock" effect can be reduced and even avoided entirely by adding such material as aniline, but aniline is expensive. One does not want to add any considerable amount of a constituent costing $1.50 to $2.00 a gallon, and aniline cannot be had for less.

The "alcogas" is a more complex material than the substitutes used in other countries. It consists approximately of one-third benzol distillate, principally benzol and toluol, a second third of alcohol products, alcohol and ether, and the remaining third of petroleum distillate, principally gasoline. The amount of ether required to easily start the engine varies according to the time of year. In winter 10 per cent., and in summer 3 per cent. is all that is essential. This American gasoline substitute has a big advantage over ordinary gasoline in that the cylinders do not carbonize. This keeping of the cylinders clean means ordinarily a greater (11 per cent.) mileage per gallon than is obtained from gasoline. On the other hand, the price of the product has been kept slightly above that of gasoline and the company making same is handicapped by the variation in the markets from time to time, of the supply and price of each of the three constituents. In other words, if the supply of benzol distillate on the market is small then it ceases to be practicable for them to put out any large amount of alcogas, no matter if they do have a surplus of the other constituents. Such an alcohol-ether mixture suffers, though not to the same extent as Natalite, with the tendency to " knock "

and to corrode the shipping containers and storage vessels. It is reported that the company have been studying this phase very carefully and that they expect soon to put out a product as free of corrosion troubles and "knocking" as good grade gasoline.   I hope they will, for it will increase our supply of motor fuel and at the same time broaden the commercial outlet for benzol products and alcohol.

The petroleum requirements of the country are steadily increasing, the amount of the increase being approximately fifty million barrels a year.   Part of this increase is due to the increase in fuel oil requirements, but a large part is also due to an increase in the gasoline requirements.   Apparently the gasoline requirement of the country is going to continue to increase and perhaps at an even greater rate than in the past.   This is well shown by the tables (page 318).

The prospects for an increased supply of petroleum from American oil wells are nil.   The investigations of the United States Geological Survey and the United States Bureau of Mines show quite definitely that the United States is approximately at its peak of production, and that within a very few years, probably within three years, the production of petroleum in the United States from wells will begin to fall off.   Moreover, the Geological Survey calls attention to the fact that we should not expect to find any more large fields of petroleum in the United States.   In other words, that practically all of the possibilities in the way of large petroleum fields in this country have been well prospected, and that now we can calculate fairly closely what the production will be in the future.   This calculation shows quite definitely that it is soon to decrease in amount.   In the past, as at present, the United States furnished approximately two-thirds of the world's production.   But we are consuming more than we are producing, for example, in 1919 the United States imported fifty-three million barrels from Mexico, and in 1920 one hundred and six million barrels.   In 1921 the importation was twenty million barrels more than in 1920.   In each year the United States has imported roughly about 60 per cent. of the total production of Mexico.

Mexican and Texas fields are short life type of fields, already they are in some places furnishing salt water instead of petroleum.

Four years ago a careful canvass of the situation showed that there was relatively little known about many of the fundamental

factors upon which a successful shale oil industry must be based. For example, almost nothing was known regarding the heat of reaction by which shale oil is formed from the organic material of the shale. Little was known regarding specific heats and latent heats, but nothing was known regarding the first reactions that

Table I.
U. S. Production Motor Vehicles.

	Passenger Trucks	Tractors
1916	1,493,617	116,670
1917	1,740,792	190,629
1918	926,388	359,947
1919	1,657,652	480,954
1920	1,883,158	525,246

Total number (9,500,000) in use in 1922 is nearly three times number in use in 1915.

Table II.
Barrels Crude Oil in U. S. (U. S. Geological Survey).

	Production	Consumption
1910	205,000,000	205,000,000
1912	225,000,000	225,000,000
1914	265,000,000	280,000,000
1916	300,000,000	320,000,000
1918	350,000,000	410,000,000
1919	377,000,000	418,000,000
1920	443,000,000	531,000,000

Table III.
U. S. Gasoline Production.

1917	2,850,000,000 gallons.
1918	3,570,000,000 gallons.
1919	3,960,000,000 gallons.
1920	4,880,000,000 gallons.

Of which 15 to 20 per cent. is produced by cracking and about 10 per cent. from casing head gas.

control the formation of oil from the organic material. In the thought that this was going to be an industry of great importance to the country and that the knowledge of the fundamental factors on which the industry is based were essential to a proper development of that industry, we undertook at Columbia University the study of these fundamental factors. I may add that since that time I have had four different graduate students working on various parts of these problems. A large part of this work is, of

course, yet incomplete, but results have been obtained that are of the utmost importance. It would take several evenings to discuss the methods used and the data obtained. To-night I can only give you results.

One of the most important factors entering into the design of a proper shale retort is that of the knowledge of amount of heat absorbed or evolved in the formation of shale oil from the organic matter of the shale. One of our men devised the first apparatus capable of directly determining this factor and found

FIG. 1.
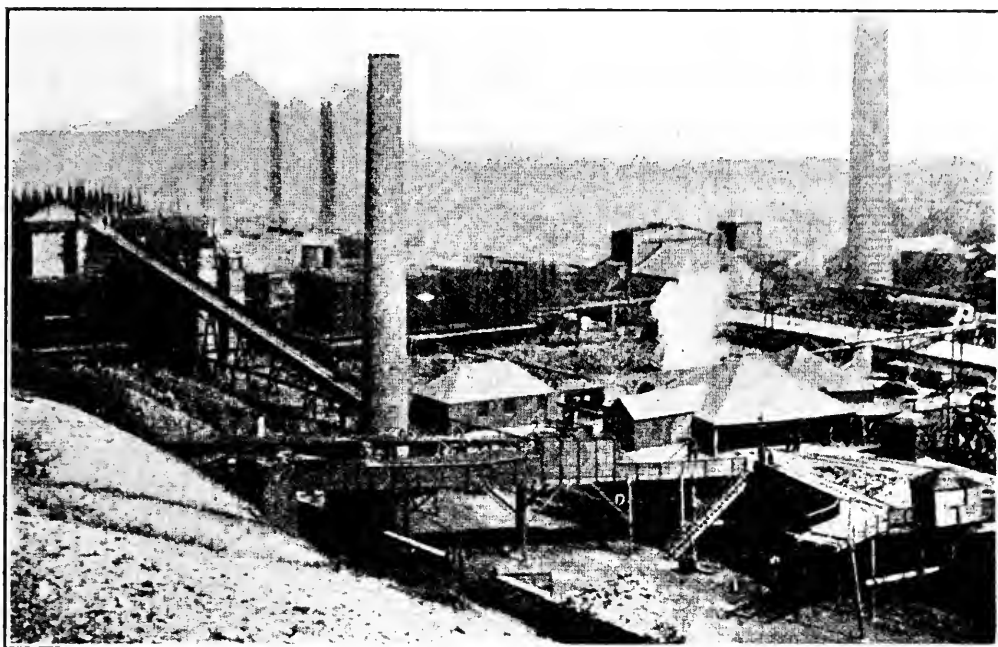
General view of the Pumperston Shale Oil Plant.

that heat was absorbed in the process, and that the amount of heat absorbed was nearly the same for shales from different sections. This heat absorption amounted in general to about 450 calories per gram of oil and gas produced, or in other terms, 160 B.T.U. per pound of average shale retorted. This is a surprisingly low figure for such a reaction.

It has been generally thought that the organic matter in shale decomposed on heating to form petroleum products as the primary products of decomposition. It has been shown by these researches in the Chemical Engineering Department at Columbia University that this is not the case, but that the primary product of the decomposition is a heavy solid or semi-solid bitumen and that petroleum

is formed by a secondary cracking process from this semi-solid bitumen. This cracking process by which petroleum products are formed is a liquid phase cracking process similar to the well-known phenomena of the cracking of petroleum to give gasoline such as that of Burton.

Another surprising thing found was that the decomposition temperature of the shale to give the semi-solid bitumen was a quite definite temperature, one with 400° and 410° C. as its limits.

The investigations have also shown to be incorrect the belief which has been held by many of those working on the developments of shale oil manufacturing process, that on heating, gasoline is the first product formed; then on higher heating kerosene; and on still higher heating lubricating oils, etc. In other words, it was shown that what happens on heating is that all these products are formed *simultaneously* by the cracking of the semi-solid bitumen first formed.

The true oil shale is a clayey or sandy, shaley deposit from which petroleum may be obtained by distillation, but not by treatment with solvents. Sometimes certain sand deposits are saturated with oil or asphalt. From these the oily constituents can be removed by solvents and, accordingly, are not commonly considered as true oil shales, but instead, go under the name of oil sands. Moreover, they are relatively small in extent and apparently have minor industrial possibilities.

Oil shales vary among themselves not only in yield of oil per ton of shale, but also in type of oil, type and character of minor constituents, and also even in the gangue material which carries the organic portion.

In Scotland they are working oil shales which furnish but 20 to 22 gallons of oil per ton of shale mined. In this country we have large deposits of shales which are able to give a much higher yield of oil. The largest of these deposits are the Green River shales of Colorado, Utah and Wyoming. There are also large deposits in Nevada, California, Kentucky, Indiana, Ohio, New Brunswick and Nova Scotia, and smaller deposits, though large enough for commercial exploitation, in many other portions of this continent. There are similar deposits in other parts of the world. Of these deposits which are likely to be exploited in the next decade, we have variations in yield from 20 gallons to 60 or even 80 gallons per ton. The large deposits of better grade will

give about a barrel (42 gallons) of oil per ton of rock. The character of oil produced in some cases is apparently a straight asphalt type petroleum similar to California well petroleum. Other shales give a large quantity of paraffin wax of even better quality than that given by the best oil wells of Pennsylvania's history. In the opinion of the speaker the average petroleum to be made from American oil shale will resemble most closely the

FIG. 2.

Massive shale, Utah.

petroleum obtained from the present mid-continent field, such as the Oklahoma oil.

It is not commonly appreciated how large these oil shale deposits are. If we consider only those oil shales which will furnish a barrel or better of petroleum per ton of shale (a barrel is 42 gallons) we have in the Green River section alone in known deposits sufficient to furnish 64 thousand million barrels of petroleum. This is an enormous amount. It is eight times larger than the total of the well petroleum that this country has produced since Colonel Drake drilled the first oil well in 1859 at Titusville, Pennsylvania. It is more than five times the total production of the world since well petroleum became commercial sixty years ago.

If we are to have gasoline in quantity from shale oil we must

make the crude shale oil and then crack it by some one of the oil cracking schemes. By the most used present method of cracking, that used by the Standard Oil Company, the gasoline as made will not be one of high quality. It will be strong odored, will color on standing, and will be inclined to carbonize the cylinder.

FIG. 3.
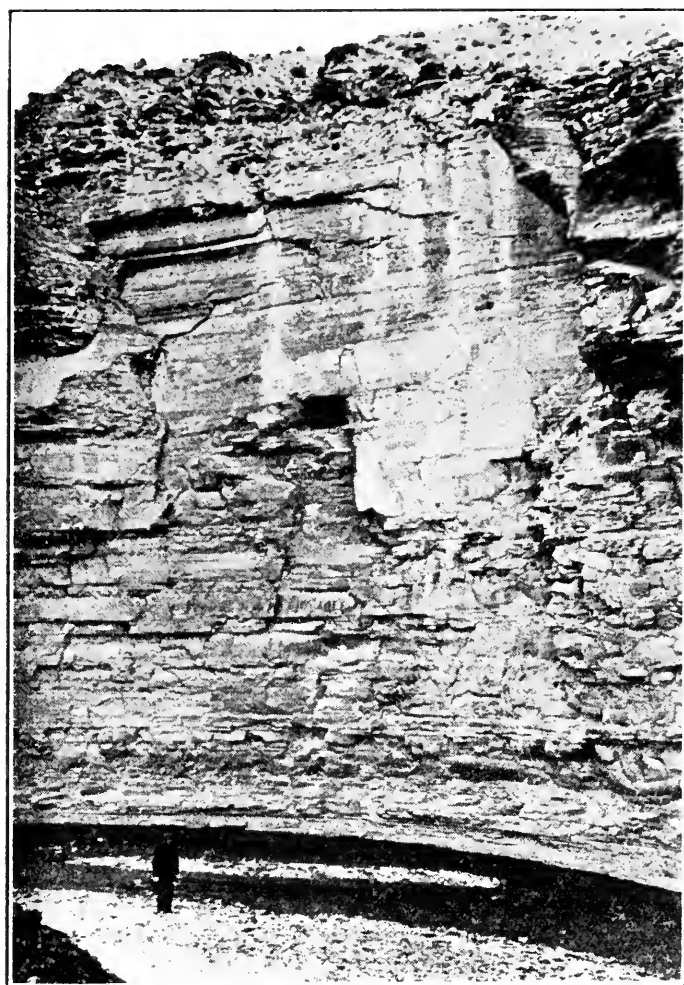
Oil shale cliff, Utah.

On the other hand, its heat value per gallon will be greater and, accordingly, in a properly designed motor it should give a slightly higher mileage than old fashioned gasoline. On the other hand, if we used the McAfee process of cracking, we would get stable, water white, well keeping, pleasant odored·gasoline of the old type. However, it is to be remembered that the McAfee process is a more expensive type of oil cracking. At present in

Scotland they are using the ordinary scheme of cracking in which considerable quantities of unsaturated compounds are formed, as high as 60 per cent. This motor spirit is commonly used by the public and it is not considered by the general public in that country to be of lower grade than gasoline from well petroleum.

In distilling most oil shales to get petroleum there is formed simultaneously considerable quantities of ammonia from the nitrogen constituents of oil shale. This ammonia is usually

FIG. 4.
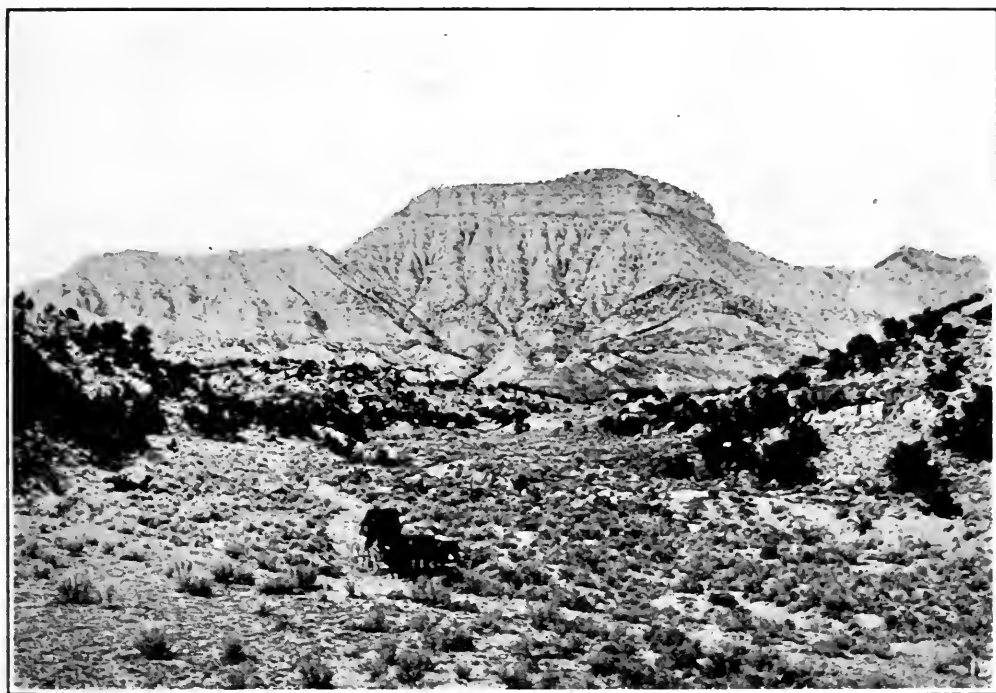
A mountain of shale, Colorado.

absorbed in sulphuric acid, recovered and sold in the form of ammonia sulphate for fertilizer uses.

A shale oil plant, then, to be successful, must be able to handle cheaply and efficiently large quantities of oil shale, distilling it to get the crude oil and ammonia and then crack and refine the crude oil to give a motor spirit useful commercially. The Scottish plants do this, excepting that they devote considerable attention to the recovery of paraffin wax, and it is only the oil left after the wax recovery that is distilled to give lubricating oils, gasoline and burning oils, or is cracked to give shale gasoline.

The Scottish shale retort is a retort of vertical pipe type. When we attempt to handle American oil shales in this retort we

find that they give trouble owing to the pieces of shale sticking together and sticking to the sides of the retort. This caking of the shale lumps stops the passage of the shale through the retort. For use on most American shales it is quite apparent that we must either modify this Scottish retort or devise

FIG. 5.
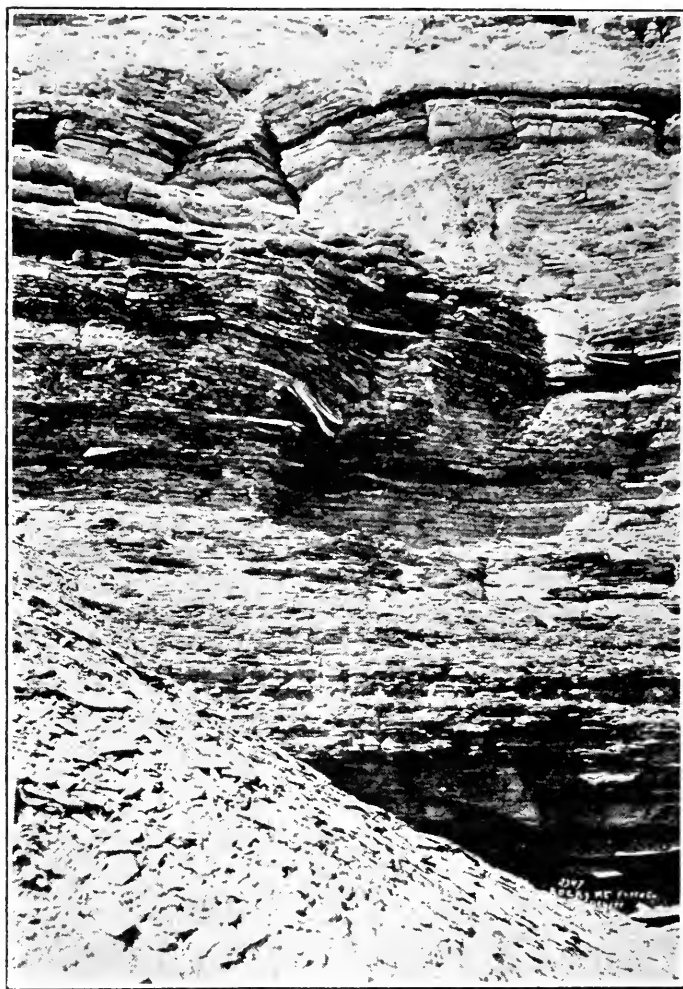
Paper shale, Colorado.

retorts on new lines. The Scottish retort is designed with the dual purpose of recovering ammonia from the shale and the obtaining of oils. With the American shales we have larger amounts of oil, but ordinarily distinctly less ammonia than is produced from the Scottish shale. In other words, the retort to handle the American oil shale *properly* must be one which gives its attention primarily to the production of oil in quantity and of

acceptable quality, and only secondarily to the production of ammonia. There are more than a score of retorting schemes which have been proposed by various American inventors. None of these has yet produced shale oil in large quantities. The most completely developed plant and process is that of the Catlin Shale Products Company, at Elko, Nevada. They have a plant which has produced approximately 100,000 gallons of shale oil. They have a small commercial refinery almost completed, and it is probable that the first shale oil and shale gasoline to be marketed in quantity in America will come from this plant. There are probably several other types of retorts which have been proposed for use in distilling oil shale which would, if given proper technical study and trials, develop into commercial processes. At present few except the inventor himself believe that any of these retorts is certain to be practicable when used on a large scale. The ideal process will be one permitting the operations to be carried through on a large scale with minimum labor and with the recovery of good yields of commercially utilizable products.

It is only within the last five years that serious attention has been given to the question of the development of a proper type of retorting still, and we have no reason to think but that well before the same length of time from now has passed we will have succeeded in obtaining a retorting scheme which can handle with low labor costs efficiently and economically American oil shales.

It is not commonly appreciated with how few men a manufacturing plant of chemical nature can be run. Generally speaking, in such processes labor is a minor factor, but in connection with most of the retorting processes yet proposed labor and power requirements are large and will be approximately one man per barrel of refined product, if mining as well as retorting and refining are included. This is the Scotch labor requirement, but we must reduce this labor requirement if we are to have in America a really successful shale oil industry.

I regret that the lateness of the hour forbids my discussing some of the other possible products from oil shale, such as the nitrogen bases which may yet supplant coal tar as a basis of a dye industry.

I have earlier shown you that the demands for petroleum are increasing in this country at the rate of about 50 million barrels a year. If this continues it will require each year seventy-five new

plants, each handling 2000 tons of oil shale a day and representing an investment of close to a million dollars each to give sufficient oil to meet simply this yearly increase in demands for petroleum. We have no other source of fuel oil or gasoline or gasoline substitute in prospect which promises to furnish even a minor part of this demand. In other words, we have reason to look forward to a very profitable chemical manufacturing industry which will rank with our largest manufacturing industries in its labor and capital requirements and in value of output.

On Friction When Lubricants are Employed. A. SOMMERFIELD. (*Zeit. für Tech. Phys.*, No. 3, 1921.)—In this report on the state of our present knowledge of the subject attention is directed to a series of important experiments conducted by Miss Jacob at Koenigsberg on the frictional laws for dry surfaces. Brass on brass and glass on glass were investigated. The brass was polished to the highest degree and the glass was dried in a special manner so that in both cases the presence of even the smallest dust particle was avoided. With ordinary surfaces the coefficient of friction is greater for the state of rest than it is after motion has begun, but for these clean surfaces it is the same in both instances. When one piece of solid with only an ordinarily clean plane surface rests on a similar surface that is gradually tilted, the upper piece begins to slide when a certain angle is reached and does not move at all until this angle is reached, while in the case of the specially cleaned surfaces there seems to be no lower limit to this angle. What might in the experiment be taken as the lower limit seemed to depend only on the fineness of the methods employed for detecting microscopic motions. Just as soon as there was the least trace of dirt on the surfaces the laws reverted to the usual forms. G. F. S.

A Demonstration Experiment in Photo-electricity. W. HALLWACHS. (*Phys. Zeit.*, 1918, page 194.)—H. Greinacher described the following experiment: A freshly cleaned surface of zinc is connected to a sensitive gold leaf electroscope and is illuminated from an arc lamp placed 20 cm. away. A strong current of air from a bellows plays on the zinc. At once the electroscope begins to show a positive charge which increases until a maximum potential of about 100 volts is attained. Without the light the air current produces no effect. Professor Hallwachs, of the Dresden Technical Institute, calls attention to his having published this same experiment twenty-eight years earlier and welcomes this confirmation of his own observation. In those early days of the photo-electric effect the real cause was not known. Now it is recognized that the light incident on the surface sets free electrons which, carrying off charges, leave the metal positive. G. F. S.

FOGS AND CLOUDS.* †

BY

W. J. HUMPHREYS, C.E., PH.D.

Professor of Meteorological Physics, United States Weather Bureau,
Department of Agriculture, Washington, D. C.
Associate Editor, Member of the Institute.

INTERNATIONAL DEFINITIONS AND DESCRIPTIONS OF CLOUD FORMS, AND SUPPLEMENTARY REMARKS.

1. Cirrus (Ci.).—*"Detached clouds of delicate appearance fibrous (thread-like) structure and feather-like form, generally white in color.* Cirrus clouds take the most varied shapes, such as isolated tufts of hair, *i.e.,* thin filaments on a blue sky, branched filaments in feathery form, straight or curved filaments ending in tufts (called *cirrus uncinus*), and others. Occasionally cirrus clouds are arranged in bands, which traverse part of the sky as arcs of great circles, and as an effect of perspective appear to converge at a point on the horizon and at the opposite point also if they are sufficiently extended. Cirro-stratus and cirro-cumulus also are sometimes similarly arranged in long bands." (Figs. 3, 4, 5, 6 and Figs. 68, 69 of *Physics of the Air.*)

An interesting form of cirrus clouds is the familiar " mares' tails " (Fig. 68, *Physics of the Air*), especially when a considerable number of them occur in the same region of the sky. These are only thin streaks of snow into which a little ball of rising cloud is drawn out, partly by the slow descent of the snow itself, and partly by the increase of wind velocity with elevation.

The cirrus occurs at greater heights than any other type of cloud—roughly 5 miles in polar regions, 7 miles in middle latitudes and 9 miles within the tropics. Since it occurs above all other clouds it also is the coldest, ranging from 50 degrees Fahrenheit below zero near the poles to 90 degrees below in the neighborhood of the equator, the difference in temperature

---

* Based on a lecture given before the Section of Physics and Chemistry of The Franklin Institute on January 5, 1922.

† Concluded from p. 230, vol. 193, February, 1922.

being due to the difference in height. Furthermore, because it is the coldest of the clouds it likewise is the thinnest, being formed in air whose water content, owing to its low temperature,

FIG. 3.

Cirrus. (F. Ellerman, photo.)

must be very small. Indeed, the sun and moon are sharply outlined through it. Finally, as its temperature is so very low the cirrus nearly always (there seem to be occasional exceptions) consists of snow crystals.

As just stated, the cirrus occurs at higher levels than does any other type of cloud. But it also occurs, under favorable conditions, at any other level, even down to the surface. It is only a shallow,

FIG. 4.

Cirrus. (F. Ellerman, photo.)

or thin, cloud of fine snow crystals (except rarely) drawn out by the wind into more or less parallel, fine streaks. Its chief cause appears to be the further cooling, by expansion due to ascent, of air already cold and holding but little moisture, and the dragging

out of the slight cloud thus formed into streaks and whirls by the winds in which it occurs.

When the cirrus slowly disappears, leaving a clear sky, fair

Fig. 5.
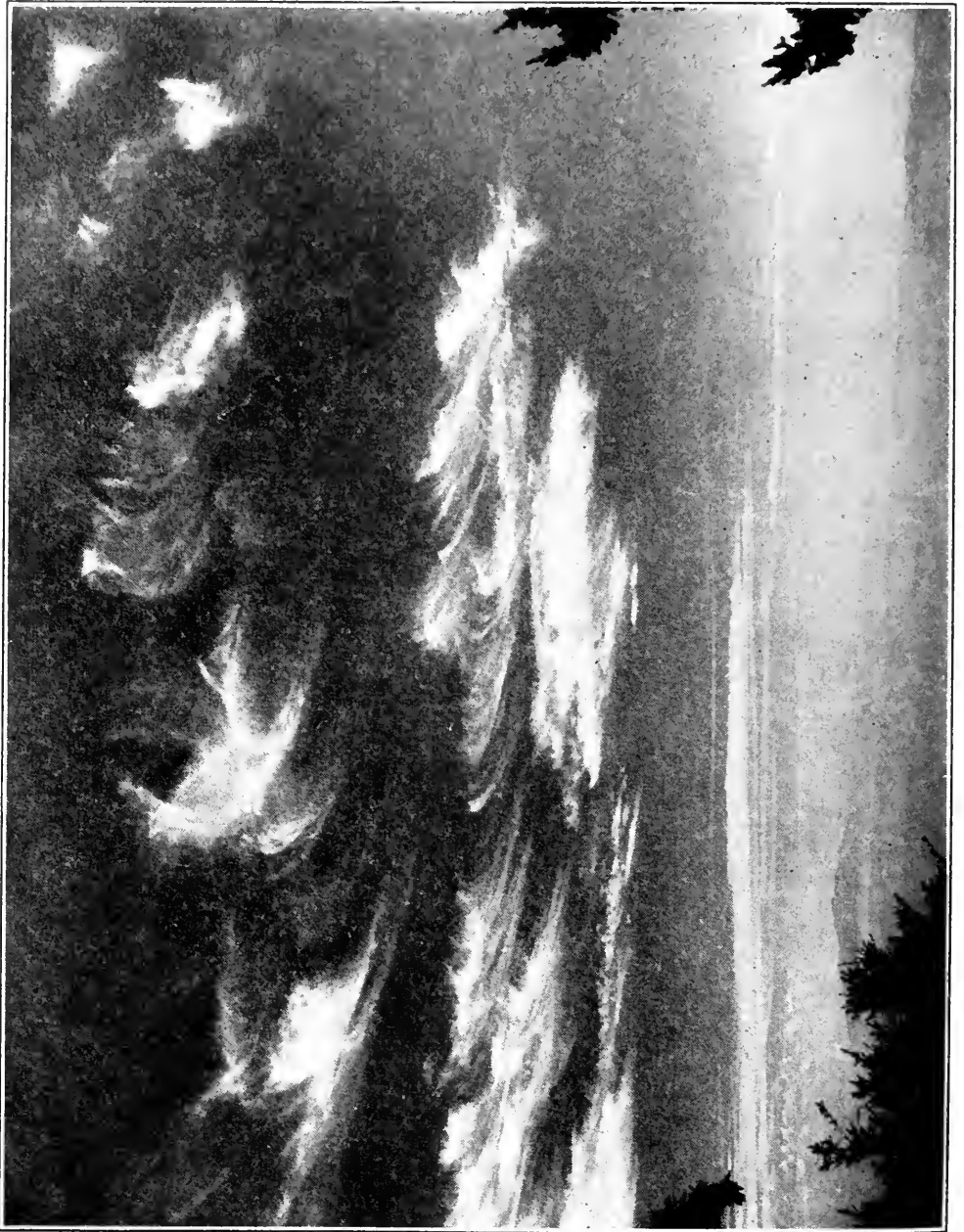
Cirrus, seen from Mount Wilson, Cal. (F. Ellerman, photo.)

weather is probable for at least a day or two. On the other hand, when it gradually thickens and merges into a nearly continuous and formless sheet, rain or snow usually begins within a few hours.

2. Cirro-stratus (Ci.-St.).—"*A thin sheet of whitish cloud;*

sometimes covering the sky completely and merely giving it a milky appearance; it is then called cirro-nebula or cirrus haze; at

FIG. 6.

Cirrus, merging into cirro-cumuli.   (F. Ellerman, photo.)

other times presenting more or less distinctly a fibrous structure like a tangled web.   This sheet often produces halos round the sun or moon."   (Figs. 7, 8.)

The halos here referred to are of two kinds: (*a*) Those due to the refraction of light into rainbow colors on its passage through

Fig. 7.

Cirro-stratus, above; advection fog, below; seen from Mount Wilson, Cal. (F. Ellerman, photo.)

ice crystals; and (*b*) those produced by the mere reflection of light (hence white or colorless) by the faces of these crystals.

The most common of the first class of halos are: (1) The circle of 22 degrees radius about the sun or moon (Fig. 9); (2) the similar circle of 46 degrees radius; and (3) the circumzenithal

arc, a brilliantly colored arc having the point directly overhead as
its centre, but appearing on the side next the sun only.   The chief

FIG. 8.
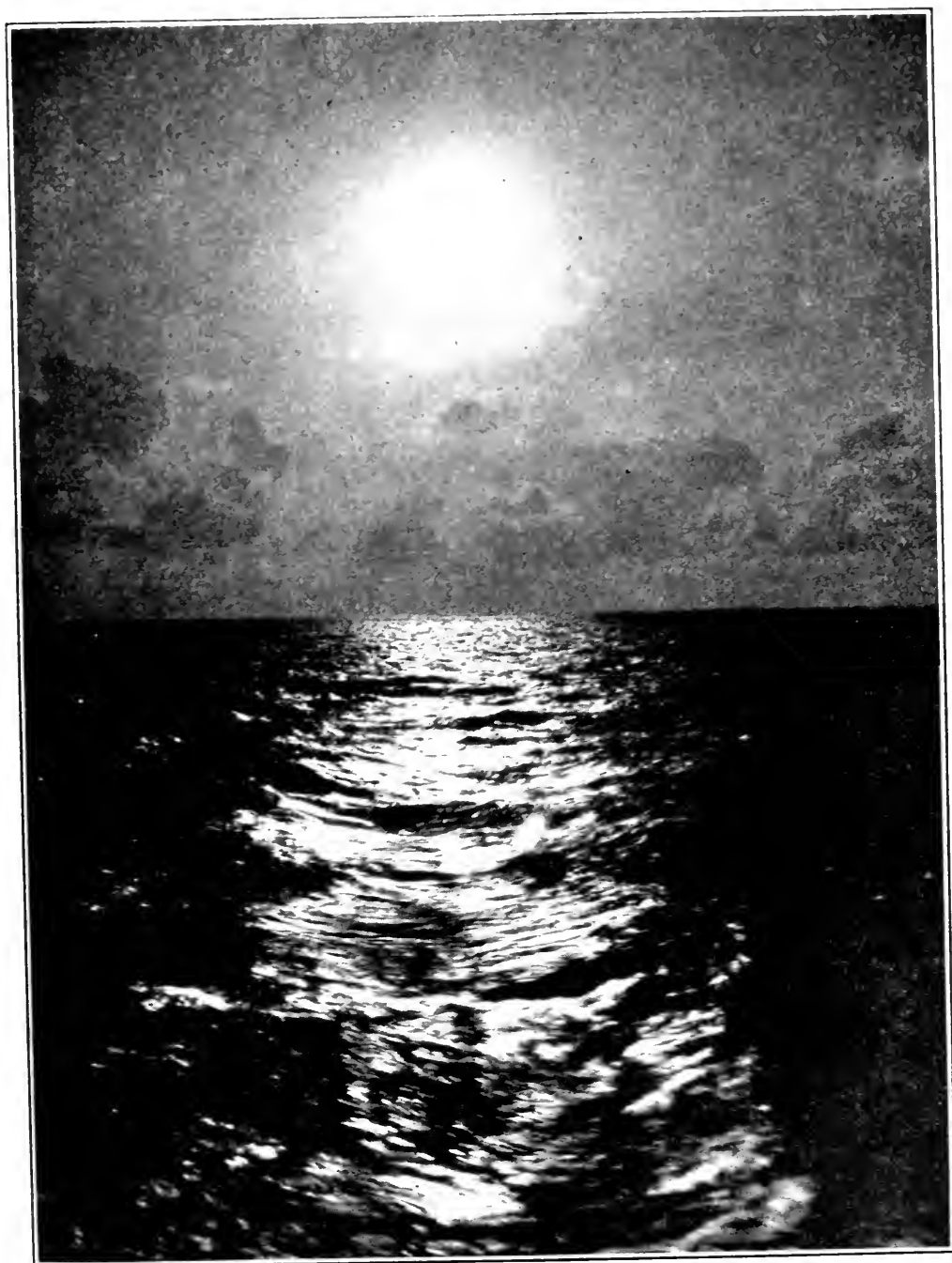
Cirro-stratus, above; cumulus, below.   (M. Mott-Smith, photo.)

halos of the second or reflection class are (1) the parhelic circle, a
white band of light passing around the sky parallel to the horizon

and through the sun (Fig. 9); and (2) the sun pillar, a vertical column of white light extending directly above and below the sun.

These halos are positive proof that the cirro-stratus clouds, like

Fig. 9.

Halo of 22° and parhelic circle. (Contributed by A. M. Coney.)

the cirrus from which they frequently are developed, also consist, normally, of myriads of ice crystals.

Whenever the cirro-stratus cloud has developed from a cirrus

it may be assumed that rain or snow, as determined by the tem-
perature, probably will soon follow, not out of the cirro-stratus,
of course, but from an approaching nimbus, or rain cloud.

FIG. 10.

Cirro-cumulus. (E. E. Barnard, photo.)

Though denser than the cirrus, the cirro-stratus still is so thin
as to leave the outline of the sun sharply defined.

3. Cirro-cumulus (Ci.-Cu.).—"*Mackerel Sky.—Small*

rounded masses or white flakes without shadow, or showing very slight shadow; arranged in groups and often in lines. French,

FIG. 11.

Cirro-cumulus, with alto-cumulus merging into stratus to the left, from the Ebro Observatory, Tortoso, Spain.

Moutons—German, *Schäfchen-wolken."*   (Figs. 10, 11 and Fig. 71, *Physics of the Air.*)

The term "mackerel sky" is an abbreviation of "mackerel-back sky," so named because of the frequent resemblance of rows of cirro-cumuli to the patterns (not the scales) on the backs of

Fig. 12.
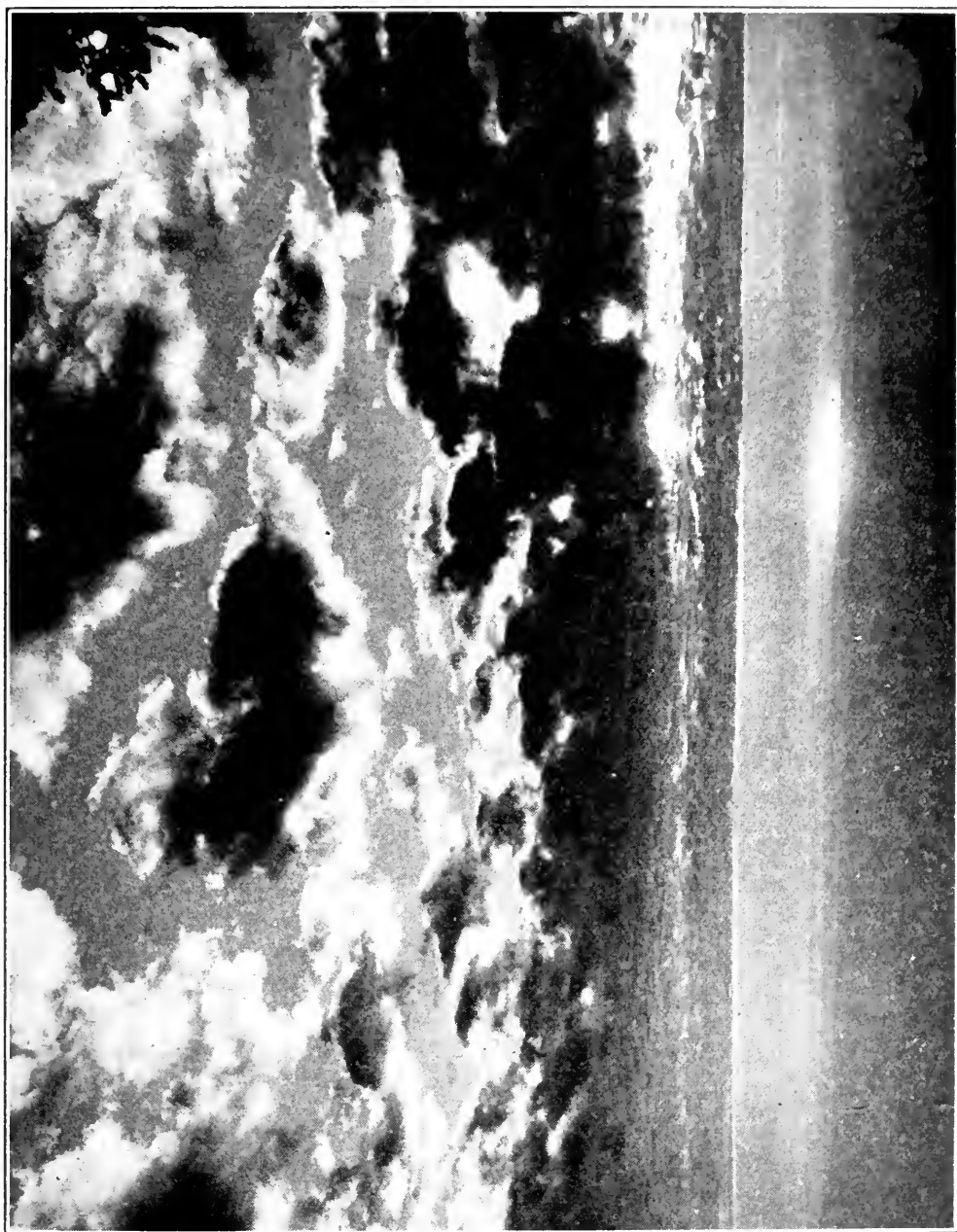
Alto-cumulus, seen from Mount Wilson, Cal.   (F. Ellerman, photo.)

one or more species of mackerel. When the cirro-cumuli are small, numerous and without order or pattern they often are called "curdle sky." (Fig. 11.)

All forms of the cirro-cumulus appear to be due to small local

convections. Those occurring in rows presumably are on the crests of air waves or billows at the interface between wind layers of unequal speeds or different directions, or both, and commonly
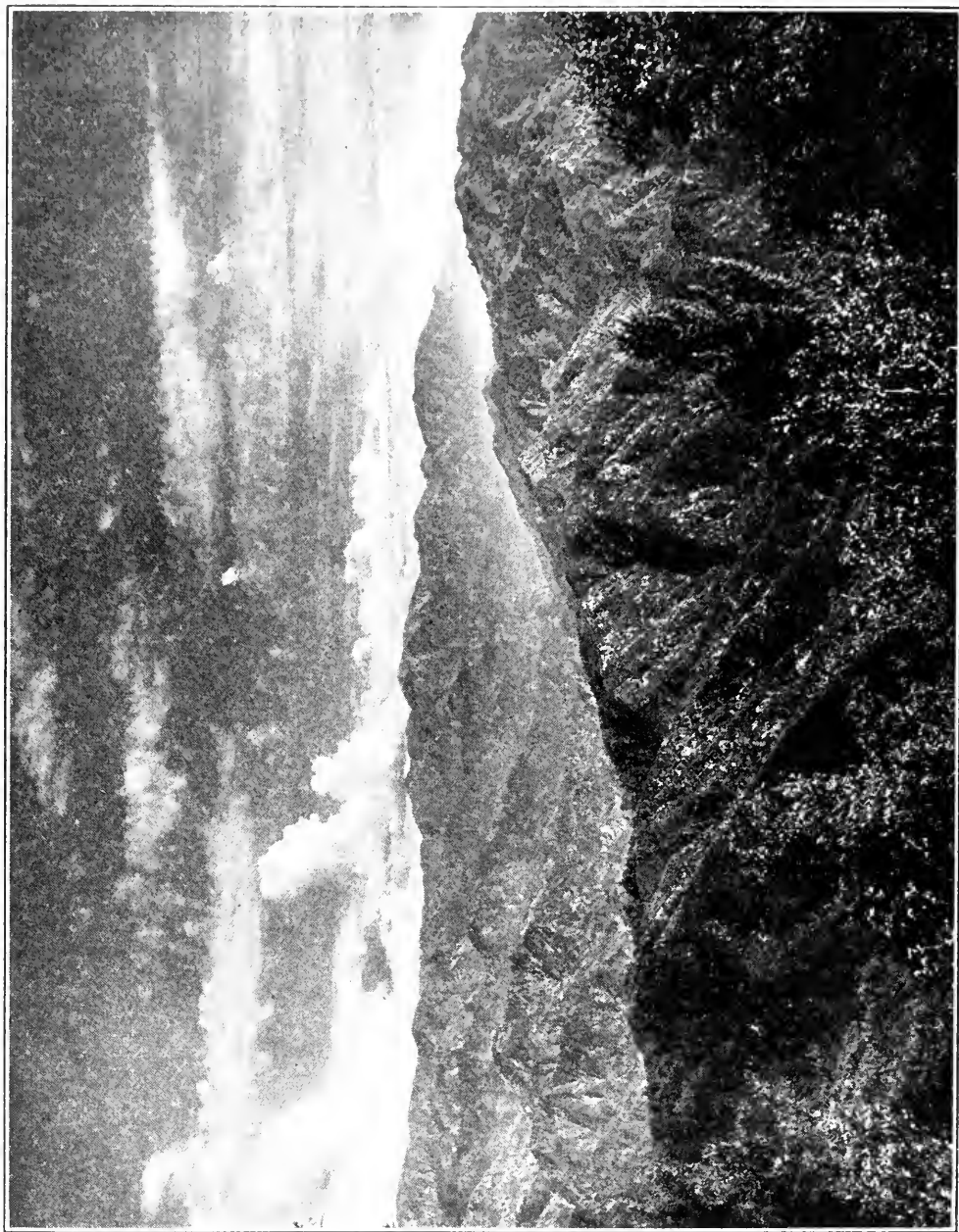
unequal also in temperature and humidity. The cirro-cumulus, through turbulence or other cause, often merges into a more or less uniform, stratified cloud, especially the cirro-stratus.

The fact that the cirro-cumuli cast but faint shadows, if any,

and that the sharp outline of the sun is visible through them shows that they are quite thin and contain but little cloud material.

4. Alto-cumulus (A.-Cu.).—*"Larger rounded masses, white or grayish, partially shaded, arranged in groups or lines, and often so crowded together in the middle region that the cloudlets join.* The separate masses are generally larger and more compact (resembling strato-cumulus) in the middle region of the group, but the denseness of the layer varies and sometimes is so attenuated that the individual masses assume the appearance of sheets or thin flakes of considerable extent with hardly any shading. At the margin of the group they form smaller cloudlets resembling those of cirro-cumulus. The cloudlets often group themselves in parallel lines, arranged in one or more directions." (Figs. 12, 13 and Figs. 73, 80, 81, *Physics of the Air.*)

The alto-cumuli appear to be due to local convections, caused either by differences of temperature or by wave motion, analogous to those that produce the cirro-cumuli, but are at lower levels, roughly two and one-half miles high, usually larger in volume and of more humid air. They frequently form in the early forenoon after a clear sunrise in consequence of scattered convection in a humid layer of air—humid from the evaporation in it of a previous sheet of alto-cumuli, or owing to moisture from the spread-out tops of thunderstorm clouds. After sundown this type of cloud frequently evaporates, through the process of cooling, contracting, and then sinking to a warmer and drier level.

5. Alto-stratus (A.-St.).—*"A dense sheet of a gray or bluish color, sometimes forming a compact mass of dull gray color and fibrous structure.* At other times the sheet is thin like the denser forms of cirro-stratus, and through it the sun and the moon may be seen dimly gleaming as through ground glass. This form exhibits all stages of transition between alto-stratus and cirro-stratus, but according to the measurements its normal altitude is about one-half of that of cirro-stratus." (Fig. 14, and Fig. 72, *Physics of the Air.*)

This type of cloud may be formed by the flow of warmer moist air over colder air beneath, by winds dragging out the tops of thunderstorm clouds, by the cooling in place of a layer of humid air, and by the relatively small precipitation out of alto-cumulus and cirro-cumulus.

The sun and moon when seen through the alto-stratus, alto-cumulus, or any other thin cloud of *water droplets,* are sur-

FIG. 14.
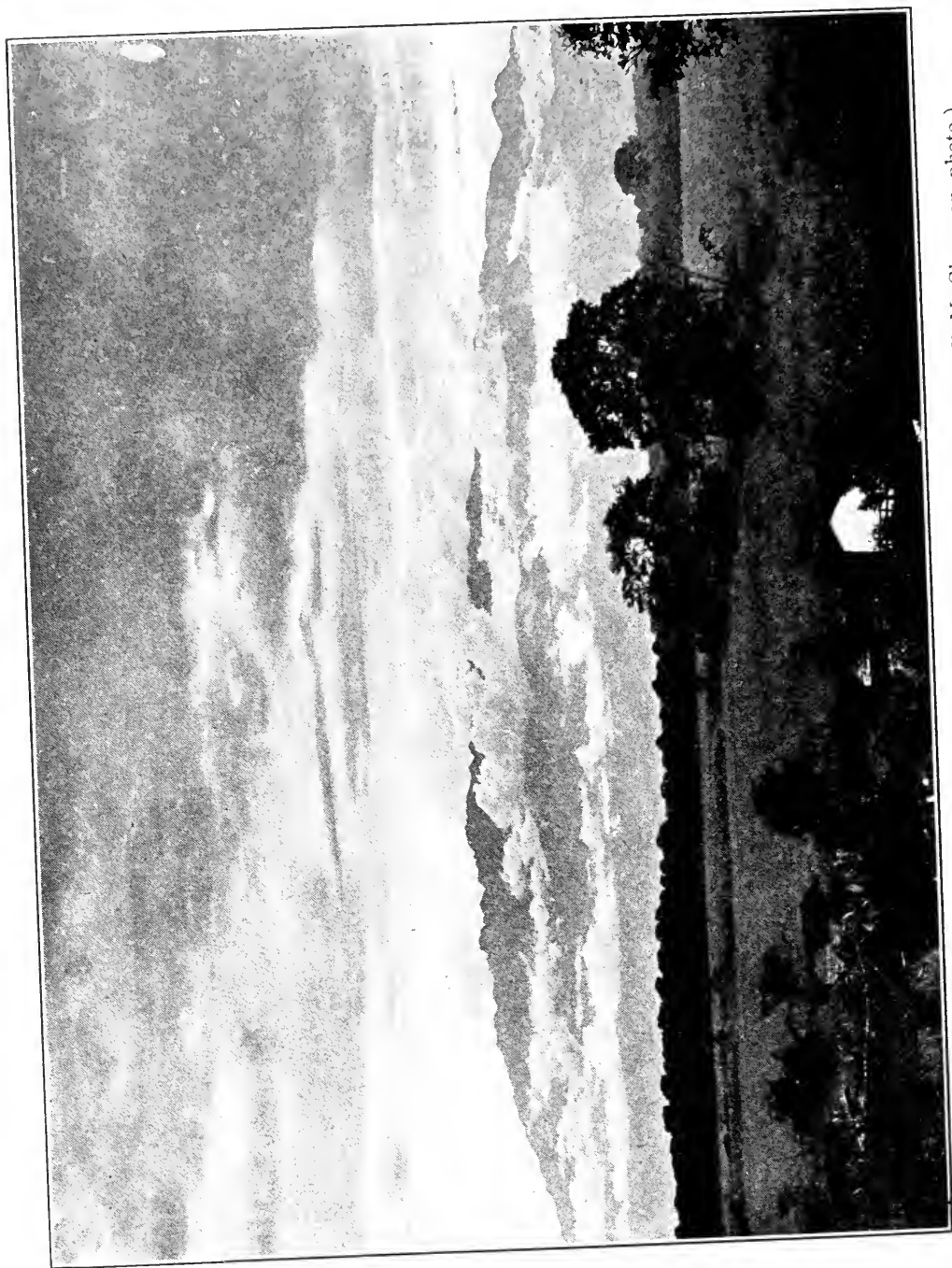
Alto-stratus, above; fracto-cumulus, below; across the Cauca Valley, Colombia.   (F. M. Chapman, photo.)

rounded by one or more sets of rings of colored light commonly only two or three diameters of the sun, or moon, away.

These small circles, in which the red is farthest from the sun, or moon, are called coronae, and are produced, as just stated,

FIG. 15.
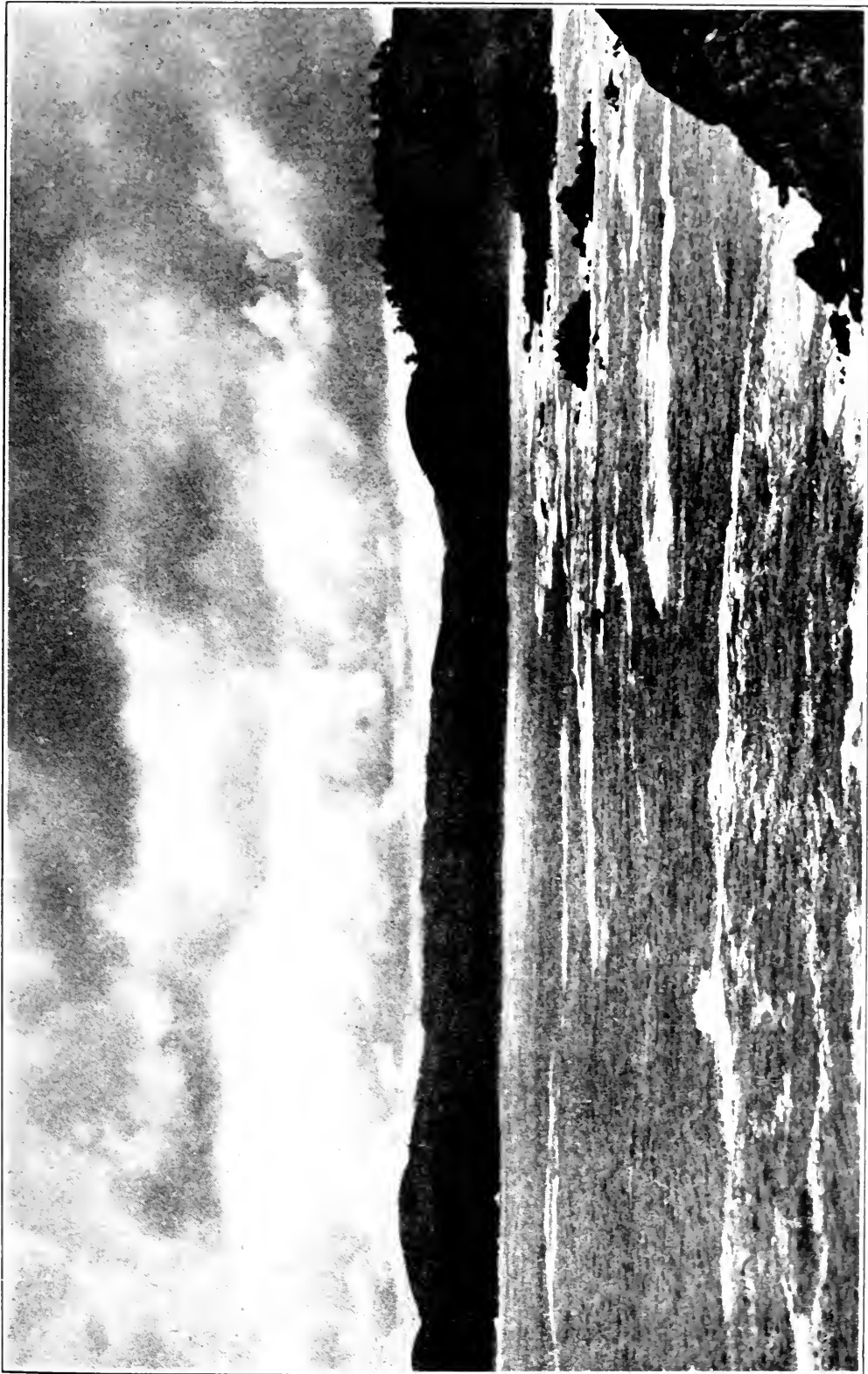
Strato-cumulus, Monterey Bay, Cal.

by the action (diffraction) of small water droplets on the light. The much larger circles, called halos, and whose red portions are nearest the sun, or moon, are caused, as previously explained, by the passage of light through *ice crystals*.

6. Strato-cumulus (St.-Cu.).—"*Large lumpy masses or rolls of dull gray cloud, frequently covering the whole sky, especially in winter.* Generally strato-cumulus presents the appearance of a gray layer broken up into irregular masses and having on the margin smaller masses grouped in flocks like alto-cumulus. Sometimes this cloud-form has the characteristic appearance of great rolls of cloud arranged in parallel lines close together. (*Roll-cumulus* in England, *Wulst-cumulus* in Germany.) The rolls themselves are dense and dark, but in the intervening spaces the cloud is much lighter and blue sky may sometimes be seen through them. Strato-cumulus may be distinguished from nimbus by its lumpy or rolling appearance, and by the fact that it does not generally tend to bring rain." (Fig. 74, *Physics of the Air.*)

This cloud, of which there are several forms ranging from the stratus of uneven density through the great parallel rolls to the sheet of well-nigh discrete cumuli, is always due to vertical convection. The more nearly discrete or separate masses are produced by the rising of warm air (thermal convection), while the irregularities in the stratus form appear to be caused, in large part at least, by mechanical turbulence. This last type (Fig. 15), might well be called turbulo-cumulus. The shallow depth, and broad expanse, of the strato-cumulus often is due to an overlying layer of air of such temperature that the rising, cloud-laden column can not pass through it, and hence is forced to spread out, much as rising smoke in a room spreads out under the ceiling.

7. Nimbus (Nb.).—"*A dense layer of dark, shapeless cloud with ragged edges from which steady rain or snow usually falls. If there are openings in the cloud an upper layer of cirro-stratus or alto-stratus may almost invariably be seen through them.* If a layer of nimbus separates in strong wind into ragged cloud, or if small detached clouds are seen drifting underneath a large nimbus (the 'Scud' of sailors), either may be specified as *fracto-nimbus* (Fr.-Nb.)." (Fig. 16.)

The name of this cloud has evoked much discussion. Nimbus, originally meaning cloud and, inferentially, storm, now means snow or rain cloud. Hence many argue if rain, or snow, is falling from

Fig. 16.

Nimbus, above; fog, below; seen from Mount Wilson, Cal. (F. Ellerman, photo.)

a cloud it certainly is a rain cloud. Likewise, if rain is not falling from it, then clearly it must be some other sort of cloud. But, on the other hand, if a given cloud while raining happens to be a typical rain cloud (nimbus) what was it immediately before we saw the

rain? Again, if it happens to be raining very hard what shall we call the cloud that we can not see for the rain? Suppose that we can not see the edge of the cloud that is raining, and generally we

FIG. 17.

Stratus, above; fracto-stratus, scud, or steam cloud, below. San Gabriel Range, Cal.

can not, dare we then call it a nimbus in face of the official definition " with ragged edges "?

These are typical of the questions and quibbles the arbitrary official definition of " nimbus " has evoked.

As a matter of fact a trace at least of precipitation may be falling from a typical alto-stratus, alto-cumulus, or other form, which it would be but confusion to call nimbus. Similarly, a

FIG. 18.

Cumulus, forming from fog—rare, seen from Mount Wilson, Cal. (F. Ellerman, photo.)

typical nimbus from which rain is falling steadily looks but little different from what it did immediately before the rain began. Hence it is convenient to interpret the definition broadly enough to cover both cases. If the cloud is typically alto-cumulus, call it alto-cumulus, whatever may be falling. On the other hand, if it looks

like a rain cloud and is not a " cumulo-nimbus," described below, call it nimbus, whether it is raining or not and regardless of all edges.

FIG. 19.
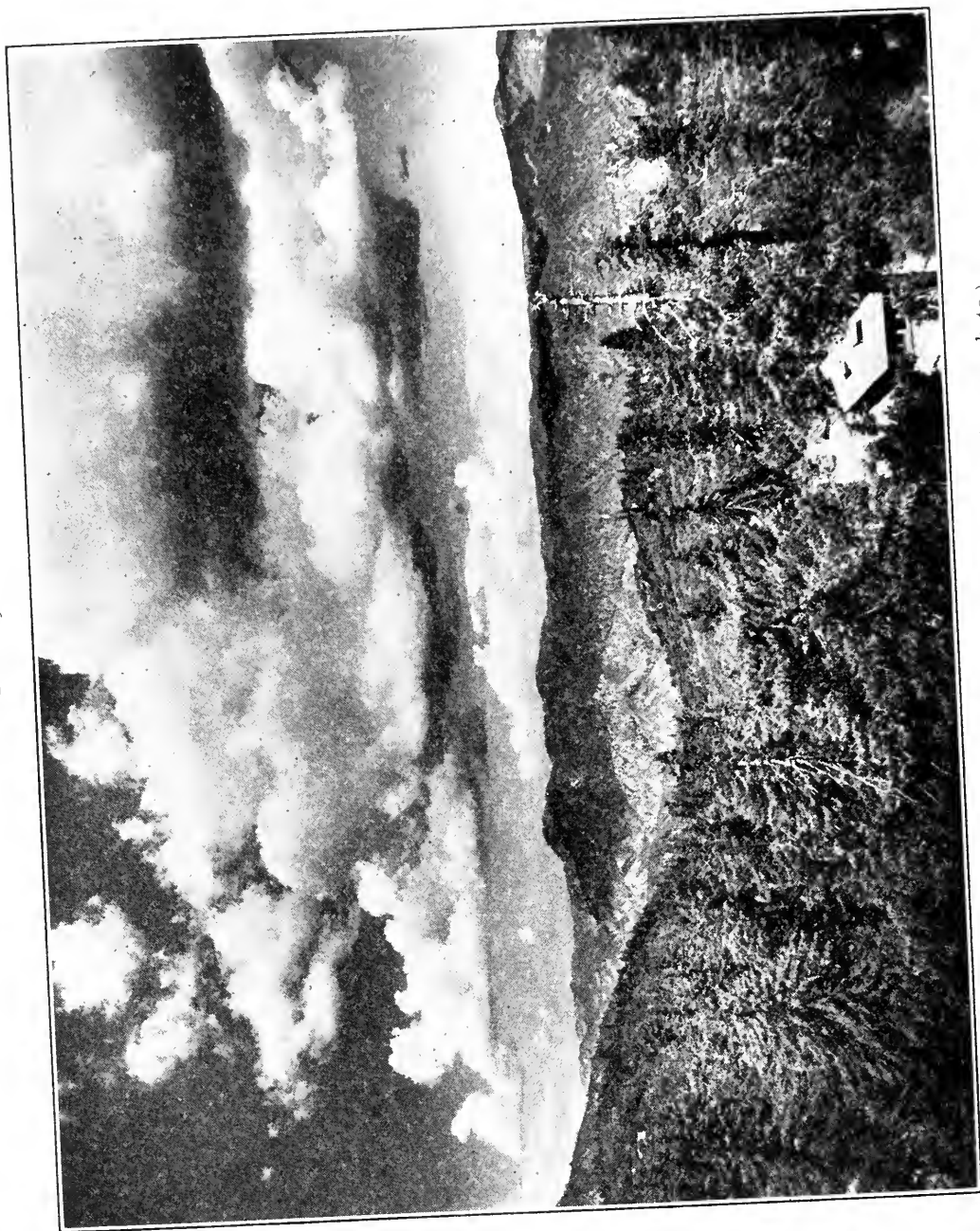
Cumulus, seen from Mount Wilson, Cal. (F. Ellerman, photo.)

Of course in taking weather notes it commonly is superfluous to say both rain and nimbus cloud, because the former nearly always implies the latter, except in the case of the thunderstorm, which is separately reported. However, if one were noting clouds

alone he certainly should say nimbus, or, occasionally, nimbus cumuliformis, whenever there is precipitation of appreciable intensity without lightning or thunder.
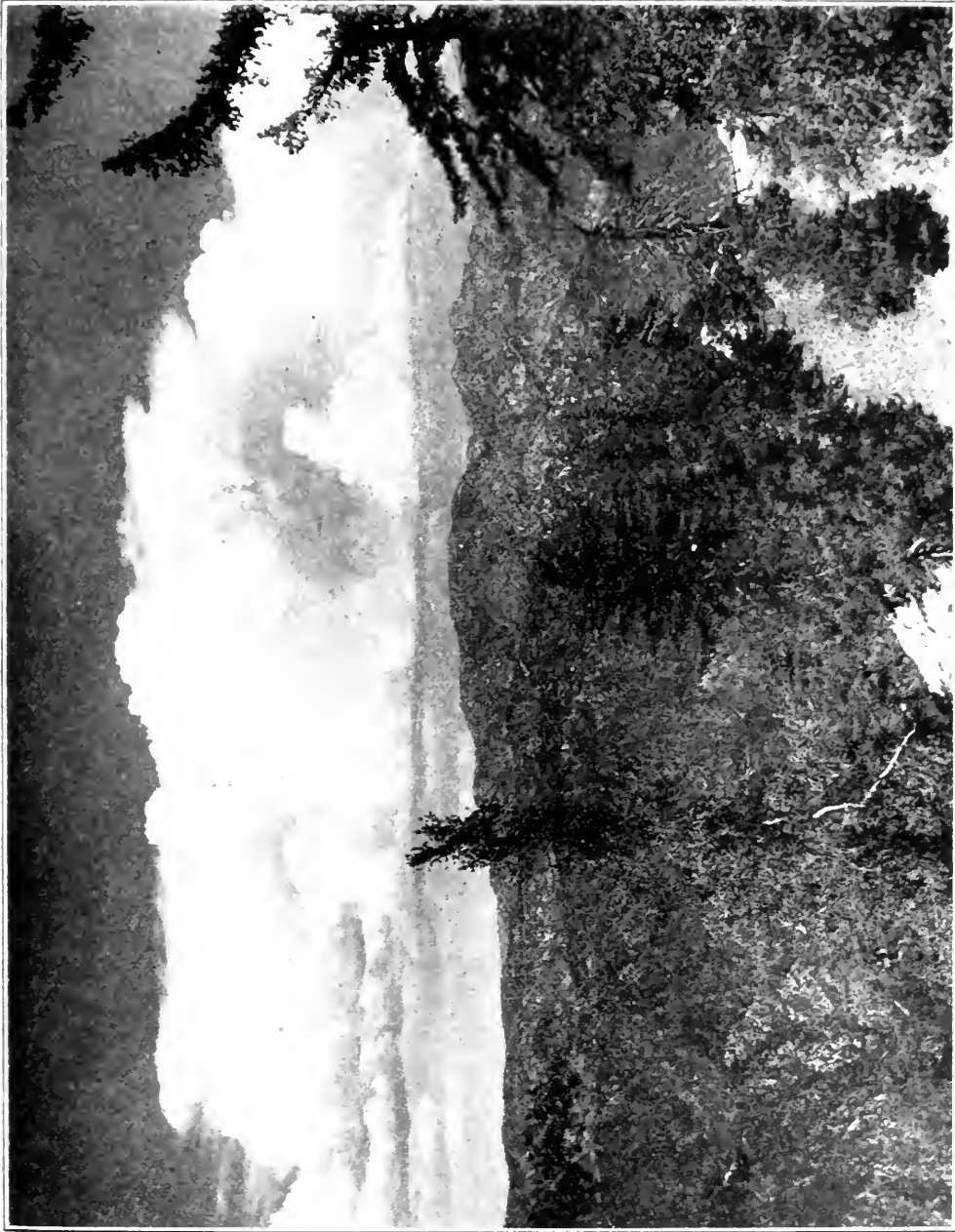
FIG. 20.

Cumulus, seen from Mount Wilson, Cal. (F. Ellerman, photo.)

This type of cloud is most frequently formed by some kind of mechanical convection, such as ascent due to converging winds, the flow of air over mountain barriers, and the over and under running of currents of different temperatures.

The fracto-nimbus, or scud, is only a low, ragged detached fragment of cloud that often rises, like steam, immediately after rainfall on a warm surface, especially the sides of mountains, which

Fig. 21.
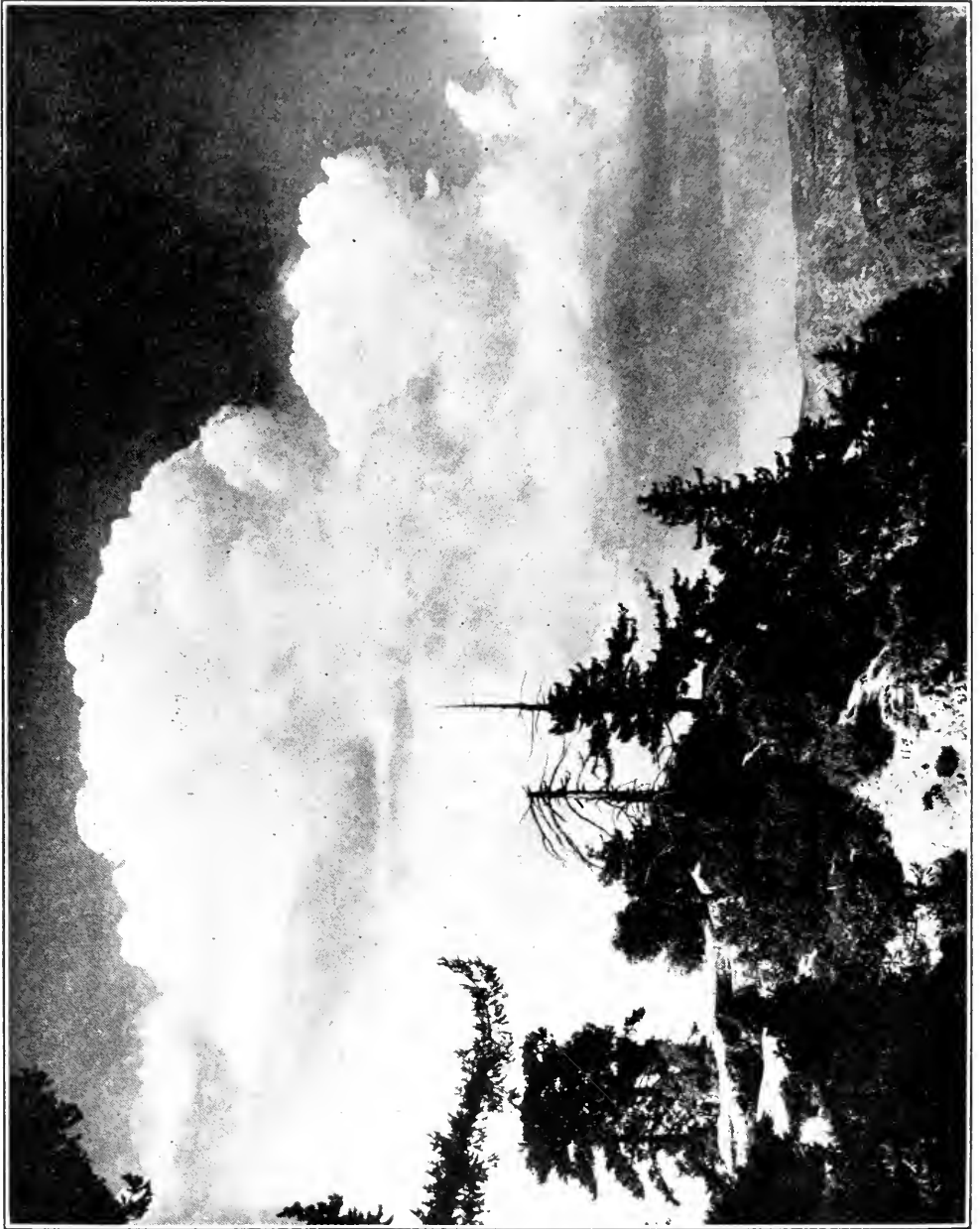
Cumulus, seen from Mount Wilson, Cal.   (F. Ellerman, photo.)

it ascends like drifting fog. (Fig. 17.) It also is frequently dragged out of a crest cloud (which see below), by the swirls of the passing wind and hurled down the leeward mountain slope.

8. Cumulus (Cu.).—"*Woolpack or Cauliflower Cloud.*—

FIG. 22.
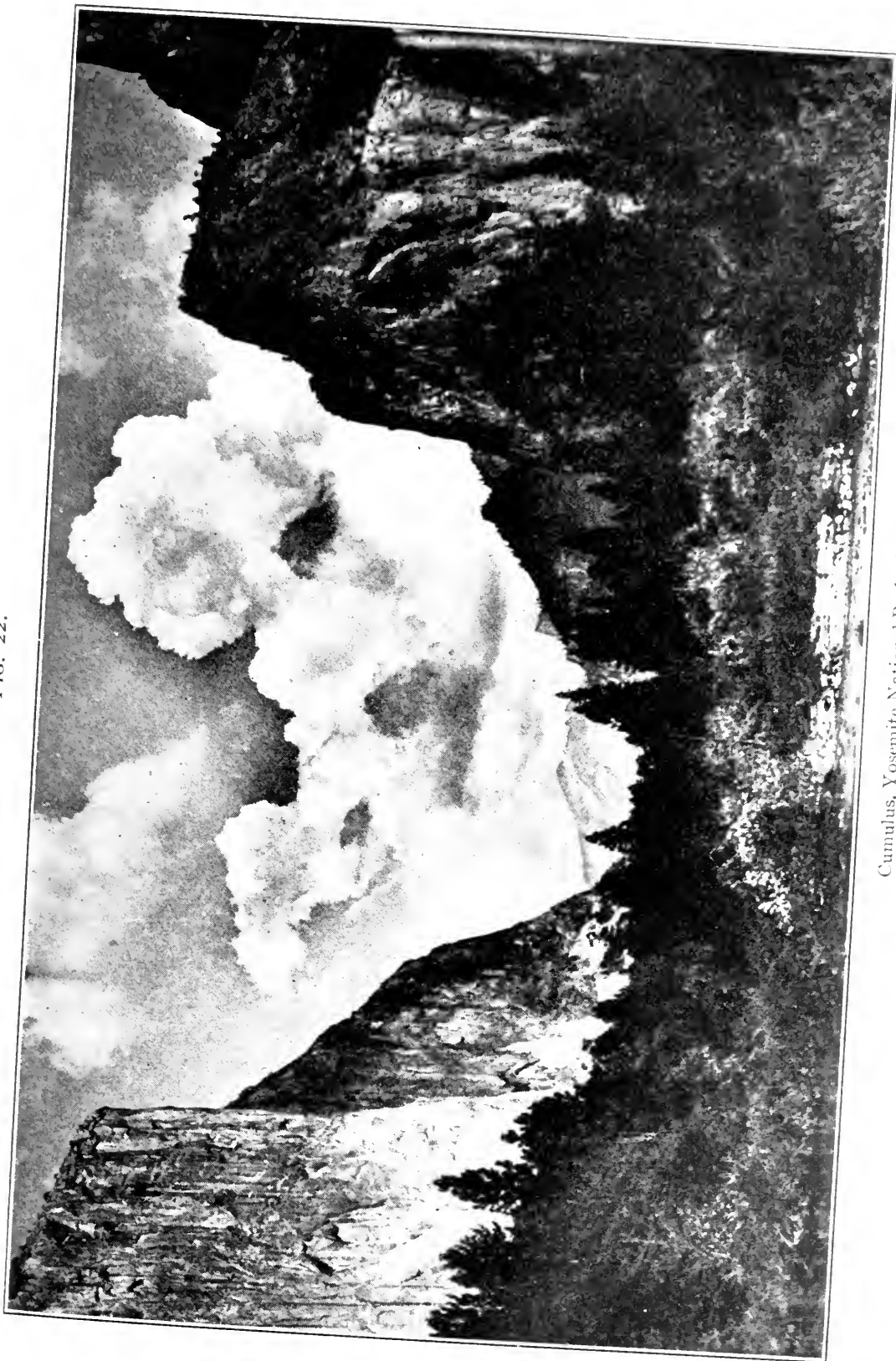
Cumulus, Yosemite National Park, Cal.

Thick cloud of which the upper surface is dome-shaped and exhibits protuberances while the base is generally horizontal. These clouds appear to be formed by ascensional movement of air in the daytime which is almost always observable. When the cloud and the sun are on opposite sides of the observer, the surfaces facing the observer are more brilliant than the margins of the

FIG. 23.
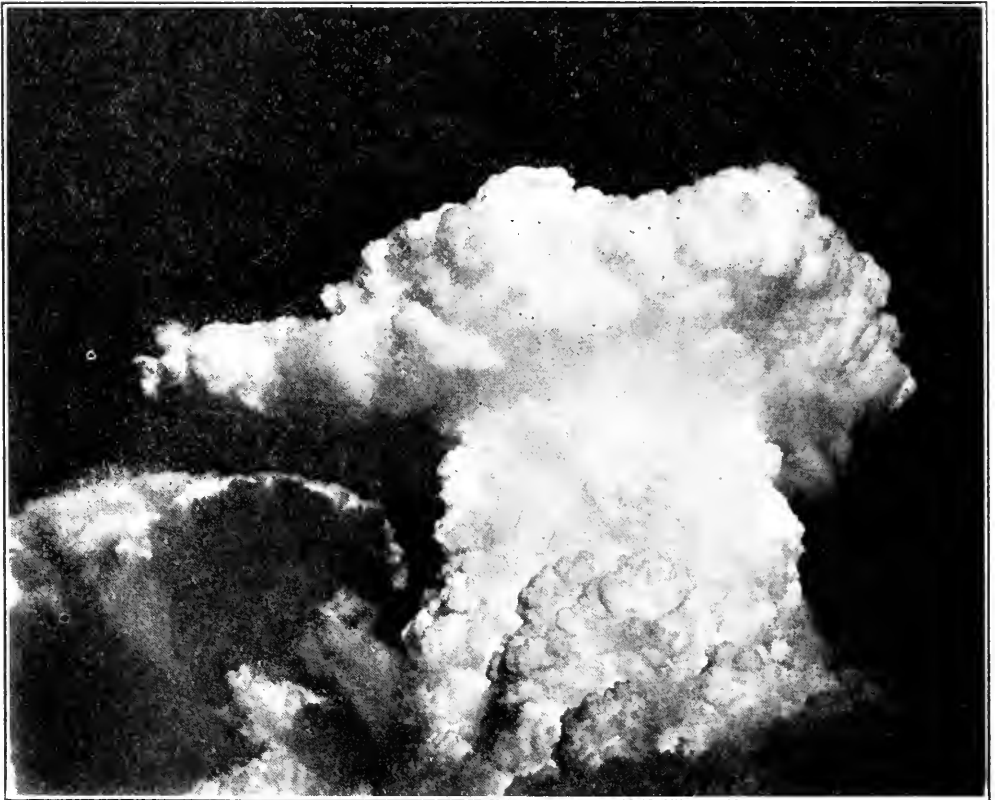
Cumulus, seen at Williams Bay, Wis.   (E. E. Barnard, photo.)

protuberances. When on the contrary, it is on the same side of the observer as the sun it appears dark with bright edges. When the light falls sideways, as is usually the case, cumulus clouds show deep shadows." (Figs. 13, 18, 19, 20, 21, 22, 23.)

" True cumulus has well-defined upper and lower margins; but one may sometimes see ragged clouds—like cumulus torn by strong wind—of which the detached portions are continually changing; to this form of cloud the name *fracto-cumulus* may be given." (Fig. 78, *Physics of the Air.*)

Even the most casual observation shows the cauliflower heads

and sides of cumuli to be in a state of rapid change and constant turmoil. All clouds of this type are caused by the lower air being so much warmer than the upper that it is forced to ascend much as

FIG. 24.
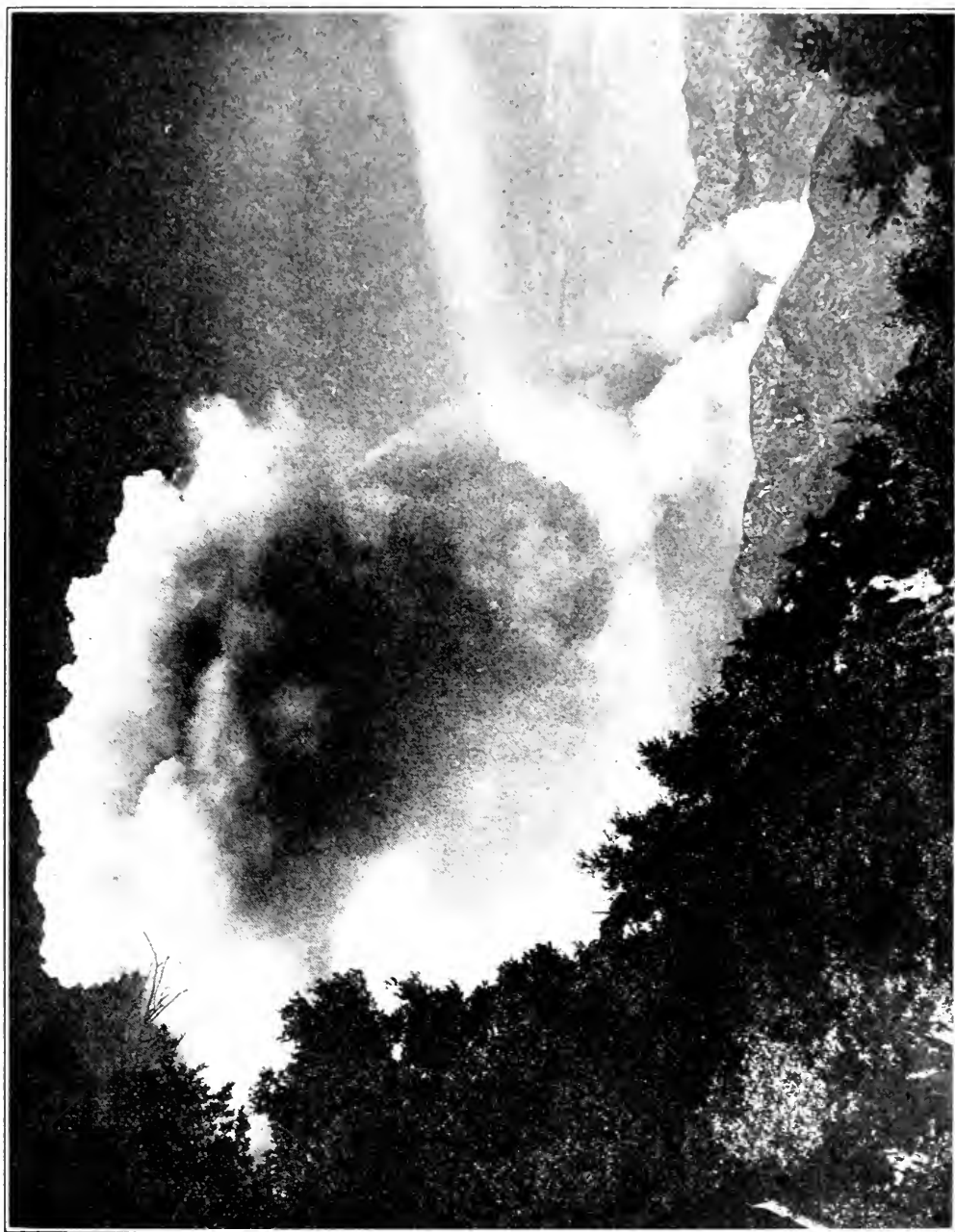
Cumulus formed by convection over fire, seen from Mount Wilson, Cal.   (F. Ellerman, photo.)

warm air is pushed up a chimney by the heavier cold air on the outside. Hence even forest fires sometimes cause the formation of cumuli. (Fig. 24 and Fig. 76, *Physics of the Air.*) However, we should remember that the fire itself adds a surprisingly large

amount of moisture to the air—a gallon of water, roughly, for every fifteen pounds of fuel burned, so that the fire cumulus is not entirely due to convection.

Since cumuli are caused by rising air currents induced by relatively high surface temperatures, they are very common in equatorial regions, and also through the middle latitudes during summer. Hence, too, they commonly occur over land most frequently during the afternoon and over water late at night. For the same reason they often follow a coast line, over the water at night and over the land through the day. Similarly, they are common over islands (Fig. 77, *Physics of the Air*), whose presence frequently is shown in this way while they themselves are still below the horizon.

9. Cumulo-nimbus (Cu.-Nb.).—"*The Thunder Cloud; Shower Cloud.—Great masses of cloud rising in the form of mountains or towers or anvils, generally having a veil or screen of fibrous texture (false cirrus) at the top and at its base a cloud mass similar to nimbus.* From the base local showers of rain or snow, occasionally of hail or soft hail, usually fall. Sometimes the upper margins have the compact shape of cumulus or form massive heaps round which floats delicate false cirrus. At other times the margins themselves are fringed with filaments similar to cirrus clouds. This last form is particularly common with spring showers. The front of a thunderstorm of wide extent is frequently in the form of a large low arch above a region of uniformly lighter sky." (Figs. 25, 26 and Figs. 75, 79, *Physics of the Air.*)

This is the most turbulent and also the thickest of all clouds, ranging in depth commonly from one to three miles and occasionally, in tropical regions, even to eight or nine miles (Fig. 112, *Physics of the Air*). Its times, places and modes of occurrence are all the same as those of the cumulus, given above.

10. Stratus (St.).—"*A uniform layer of cloud-like fog not lying on the ground.* The cloud layer of stratus is always very low. If it is divided into ragged masses in a wind or by mountain tops, it may be called *fracto-stratus*. The complete absence of detail of structure differentiates stratus from other aggregated forms of cloud." (Fig. 17.)

The stratus is the lowest of clouds, averaging round 2000 feet

above the surface. It frequently is formed by the lifting of
relatively warm humid air by under running cold winds; by the
flow of a warm humid wind over a surface stratum of cold air;

Fig. 25.

Cumulo-nimbus, Pensacola, Fla. (Lieut. W. F. Reed, Jr., photo.)

and by the drifting of deep fog from the sea over relatively warm
land, as in the case of the " velo " cloud of southern California in
which the lower portion of the fog is delightfully evaporated away

while the upper part is left as a gracious veil that shields one from the sun until nearly noon.

The same pamphlet, entitled " Cloud Forms," from which the

Fig. 26.

Cumulo-nimbus, seen from Mount Wilson, Cal.   (F. Ellerman, photo.)

above quoted definitions and descriptions of the ten standard cloud types were taken, contains also the following instructions to observers :

"(*a*) In the daytime in summer all the lower clouds assume,

as a rule, special forms more or less resembling cumulus. In such cases the observer may enter in his notes ' *stratus-* or *nimbus-cumuliformis.*'

"(*b*) Sometimes a cloud will show a mammillated surface and the appearance should be noted under the name *mammato-cumulus.* (Fig. 88, *Physics of the Air.*)

"(*c*) The form taken by certain clouds particularly on days of sirocco, mistral, föhn, etc., which show an ovoid form with clean outlines and sometimes irisation, will be indicated by the name *lenticular,* for example: *Cumulus lenticularis, stratus lenticularis* (Cu.-lent., St.-lent.).

"(*d*) Notice should always be taken when the clouds seem motionless or if they move with very great velocity."

SPECIAL CLOUD FORMS.

It may seem, no doubt, that enough cloud forms have already been mentioned to include every type known to the heavens, and thus to satisfy the most ardent cloud observer, but, in addition to the gradual transformation of a cloud from one type to another, giving stages that puzzle the expert, there are several occasional forms sufficiently distinct, even though some of them belong to the general types already mentioned, to justify individual names and special descriptions.

Billow Cloud.—Billow clouds (Fig. 80, *Physics of the Air*), also called windrow clouds and wave clouds, occur in nearly equally spaced parallel bands, generally with intervening strips of clear sky. The billow cloud most frequently, perhaps, is only a special form of the more general alto-cumulus. It also is a common form, rather as ripples, however, of the cirro-cumulus. On rare occasions it likewise occurs at low levels where it might be called a type of strato-cumulus.

But whatever its level the billow cloud is always produced in the same way—by the flowing of one stratum or current of air over another of distinctly greater density, thereby creating air billows precisely as water billows are formed on the ocean. Now, the crests or tops of these waves are cooled by expansion, having risen above their previous level, and their troughs or bottoms warmed by compression. Hence, when the under layer is practically saturated, each crest, because of this cooling, is cloud-capped, and each trough clear.

It is particularly interesting to note that although each billow cloud maintains its identity and position in the series of waves as long as it exists at all—for hours it may be—nevertheless the

Fig. 27.
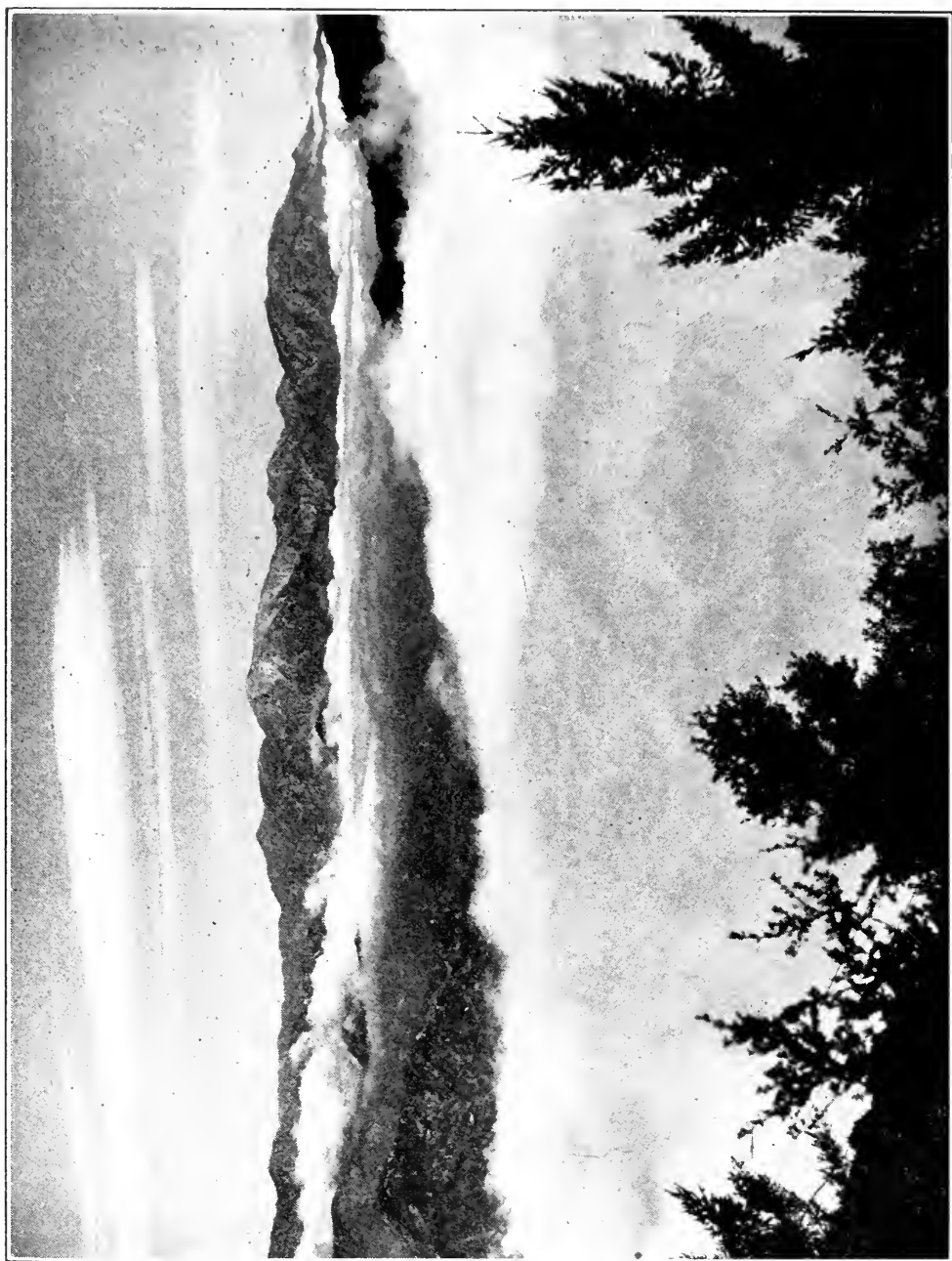
Lenticular cloud (alto-stratus lenticularis), seen from Mount Wilson, Cal. (F. Ellerman, photo.)

actual particles of which it consists at any instant have only the briefest duration, there being continuous condensation on the rising or windward side of the billow and equivalent evaporation in the descending or leeward portion.

FIG. 28.

Lenticular cloud (cumulus lenticularis).   (C. F. Brooks, photo.)

FIG. 29.

Lenticular cloud (cumulus lenticularis), seen at Flagstaff, Ariz. (C. O. Lampland, photo.)

Furthermore, while the billow cloud progresses steadily across the sky its velocity is neither that of the upper stratum nor of the lower, any more than the velocity of a water wave is either that of

the wind that is producing it or of the water in which it occurs. Wind velocity, therefore, can not be determined by measurements on clouds of this kind; nor, of course, by attempted measurements on any of the stationary types, such as those mentioned below.

FIG. 30.
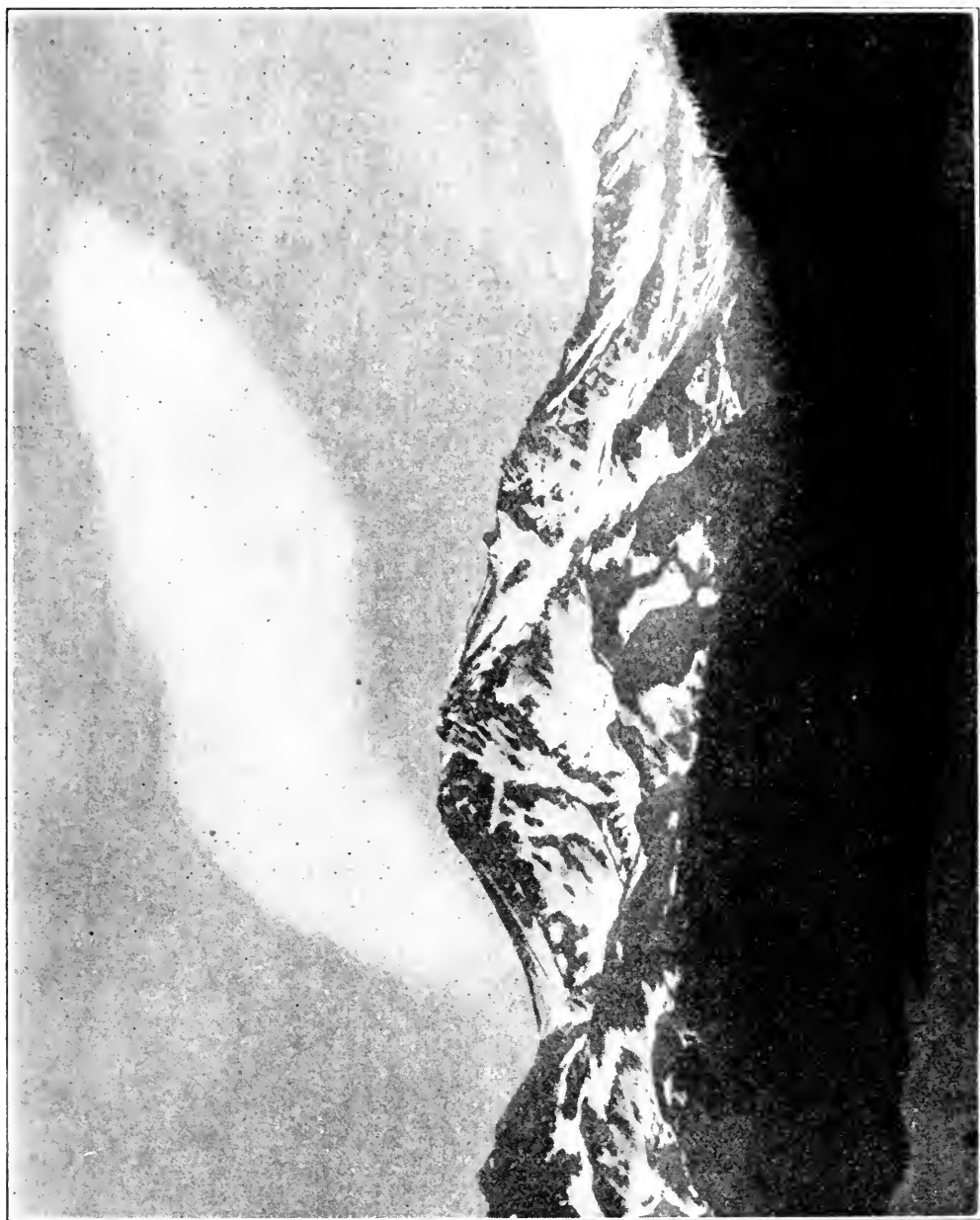
Lenticular cloud, over Mount Shasta.   (C. A. Gilchrist, photo.)

Lenticular Cloud.—The lenticular cloud (Figs. 27, 28, 29, 30 and Figs. 82 and 83, *Physics of the Air*) is only the cloud cap to a stationary or nearly stationary air billow produced as a rule by the flow of the wind over an uneven surface.   It is especially

common among high peaks and rugged mountains. Its material, like that of the crest cloud, is in rapid change—condensation on the windward side and evaporation to the leeward. Hence it is shaped like a double convex lens, the suggestive origin of its name, thickest in the middle and thinning away to nothing on either side.

As implied above this is a stationary cloud, and hence one of the several that cannot be used to measure wind velocities.

Crest Cloud.—The crest cloud (Figs. 84, 85, *Physics of the Air*) is caused by the upward deflection, and consequent cooling by expansion, of humid winds by a long mountain ridge, whose crest it commonly covers, whence its name, and whose sides it often gracefully drapes. Occasionally, however, it forms slightly above and a trifle to the leeward of the ridge along the topmost (hence coolest) portion of the deflected wind current. In either case the cloud is permanent in position only, being continuously created (condensed) on the windward or ascending and cooling side, and destroyed (evaporated) on the lee or descending and warming side.

The best known example, perhaps, of this interesting cloud is the celebrated " Table Cloth " of Cape Town pride, spread by the southeasterlies over the top and down the sides of Table Mountain.

When the obstruction is only a peak the crest cloud is apt to be called a cap, hat, cowl, hood, and the like, all of which are recognized signs of bad weather, as, for instance :

> " When Falkland Hill puts on his cap,
> The Howe o' Fife will get a drap.

> " When Traprain puts on his hat,
> The Lothian lads may look to that.

> " When Rubenslaw puts on his cowl,
> The Dunion on his hood,
> Then a' the wives of Teviotside
> Ken there will be a flood."

Riffle Cloud.—Very often the crest cloud along a mountain ridge is paralleled by a similar but smaller cloud over the leeward valley, or plain in the case of the exceptional isolated mountain. The wind, deflected in a great wave over the mountain, rises in a series of decreasing billows beyond, like the waves or riffles in a river due to a ledge or rock or other obstruction on the bottom—hence the name " riffle cloud."

The process by which the crest cloud is formed along the ridge of the mountain and restricted thereto, that is, the cooling of the air by ascent on the windward side and its warming by descent on the lee side, occurs also in the rising and falling air on the windward and lee sides respectively of the series of air waves, or giant riffles, induced by the mountain obstruction to the wind. Hence, when the crest cloud is at all heavy the top of the first and largest wave is apt to be clouded; even the second wave occasionally shows some cloud, but the third rarely if ever.

The crest cloud and the riffle cloud, since they show the presence of humid winds, are excellent signs of rain, or snow, in a few hours. The order of occurrence is: Formation of the crest cloud; thickening of the crest cloud and forming of the riffle cloud; growth and union of these two clouds and the complete covering of the sky; onset of rain or snow.

Banner Cloud.—The banner cloud (Fig. 86, *Physics of the Air*) suggests a great white flag, whence its name, floating from a tall mountain peak. In strong winds the atmospheric pressure to the immediate leeward of such a peak is more or less reduced. If the humidity is right this causes a cloud through the resulting cooling, aided, no doubt, in many cases, by the cold walls of the peak itself. Here too, as in the preceding cases, the cloud is stationary, but its substance in rapid flux through condensation on one side and evaporation on the other.

Scarf Cloud.—It occasionally happens that as a cumulus rises rapidly to a great height a thin cirrus-like cloud arch, convex upwards, forms above, and detached from, the tipmost cumulus head (Fig. 31), so suggestive of a halo as to arouse poetic if not even pious fancies. As the cumulus continues to rise this flossy cloud grows and rests like a veil over the thunder head. A little later, a few minutes at most, it mantles the cumulus shoulder (Fig. 87, *Physics of the Air*), the head or heads being free, and may even drape the sides. In all cases it has the sheen and apparent texture of a great silken scarf—hence the name. It has often been called false cirrus, but that term is now commonly restricted to an entirely different cloud. It frequently is also called a cap cloud, but this name, apart from being loosely applied to any sort of cloud on a mountain peak, is applicable, by analogy, only during the early stages of the development of the scarf cloud and hence neither distinctive nor properly descriptive.

Fig. 31.
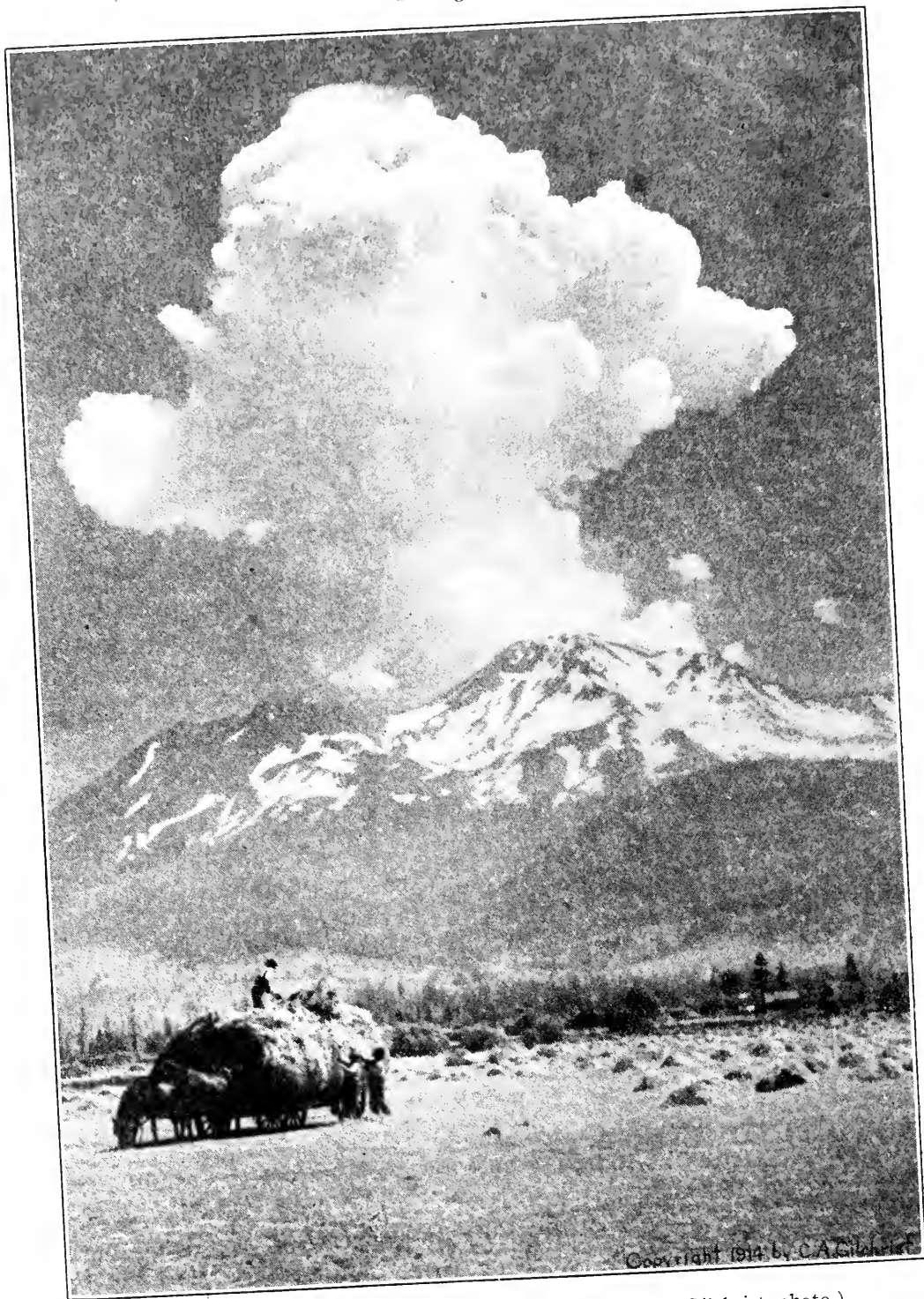
Scarf cloud, over cumulus, at Mount Ranier, Cal. (C. A. Gilchrist, photo.)

It is caused by the rising and consequent expansion and cooling of the air directly above the cumulus heads. Ordinarily this

movement and cooling of the air over the cumulus produces no
visible effect. Occasionally, however, there happens to be a
stratum of air at a considerable height (three or four miles) that

FIG. 32.

Tomitro-cirrus (false cirrus), over the Valley of Va. (A. J. Weed, photo.)

is practically saturated. When such a layer is lifted locally, as just
explained, a thin cloud, the first stage of the scarf cloud, is formed
at the place of disturbance. When this layer is thin, as it com-

monly is, the thunder heads generally pass quite through it into drier air above, leaving the scarf cloud mantling the shoulders of the cumulus, or draping its sides at about the original level of the humid stratum.

Although this is not a rare cloud, few, apparently, are familiar with it, owing to its ephemeral nature and occurrence with other clouds. It has, of course, but little of the grandeur of a towering cumulus or intricacy of a far flung cirrus, nevertheless, its

FIG. 33.

Funnel cloud (tornado cloud), seen near Elmwood, Nebr., April 6, 1919.
(W. A. Wood, photo.)

coming into existence at an unexpected place, its silken texture, and its changes in form and position all merit its being carefully looked for and closely followed when found.

Tonitro-cirrus.—The name " tonitro-cirrus," thunder cirrus, is applied to those gray locks, to speak figuratively, combed out from old thunderheads by the upper winds, and also the thinner edges of the *anvil cloud,* or spreading top of a cumulo-nimbus. (Fig. 32.)

Even though the winds of the lower atmosphere are always light when great towering cumuli are formed, the upper winds may still be strong. Clearly, then, the top of a cumulus that extends into a stratum of swift winds is certain to be drawn out

into a more or less extensive, fibrous sheet of snow crystals that differs but little, if any, from the ordinary cirrus except in its mode of origin. A more common name for this cloud is " false cirrus," but this term is objectionable since the cloud in question is indeed a cirrus, differing from other cirri, as stated, only in origin.

FIG. 34.

Funnel cloud (tornado cloud), from two exposures taken close together, upper one first, seen near Elmwood, Nebr., April 6, 1919. (G. B. Pickwell, photo.)

Mammato-cumulus.—The mammato-cumulus, called also pocky-cloud, festoon-cloud, sack-cloud, " rain balls," and several other local names, is a sort of miniature up-side-down cumulus (Fig. 88, *Physics of the Air*). It occurs most frequently in connection with severe thunderstorms, and appears to be due to irregular descents here and there of cold air onto an existing

stratus cloud, each place of fall being marked by a downward bulge in the cloud base.

Tornado or Funnel Cloud.—The tornado or funnel cloud (Figs. 33, 34, 35) is only a long funnel shaped cloud about the axis of rotation of a tornado. It hangs down, either straight or curved, from the base of a rain cloud—commonly if not always, a cumulo-nimbus—and varies in extent all the way from a mere protuberance on the parent cloud, to a crooked trunk reaching all the way to the earth. It is caused by the cooling, due to expansion, of the rotating air, to a temperature below the dew-point. In short, it is just cloud, induced, like other clouds, by cooling, though often mixed with dust in its lower portion.

CLOUD MISCELLANY.

CLOUD MATERIAL.

Clouds consist either of water droplets, always when the temperature is above freezing, or ice crystals, normally when the temperature is below freezing, but not invariably, because occasionally the droplets cool even much below the "freezing point" without solidifying.

The droplets that together constitute a cloud out of which no rain is falling vary in size from the vanishingly small, especially at the surface and edges where they are likely to be disappearing by evaporation or coming into existence through condensation, up to several fold that of the average particle. Most of them, however, appear to be about one one-thousandth of an inch in diameter, roughly the size of the familiar lycopodium spore. In rain clouds, on the other hand, such as the cumulo-nimbus, this range is much greater—from the invisibly minute, as before, up to the fully developed drop of, say, one-tenth to one-eighth of an inch across.

The ice crystals, the material of cold clouds, also vary widely in size, and include every gradation from the minute, almost microscopic, needles of the cirrus to the well-known snow flakes of the winter storm. Their chief claim, however, on our attention is not because of this interesting dimensional range, but owing to their exquisite beauty. The fundamental pattern, however simple or complex the crystal, is always the same, the hexagon, or six-sided column (Fig. 160, *Physics of the Air*), but the variety is endless:

FIG. 35.

Funnel cloud (tornado cloud).

Needles with pyramidal ends; columns, with flat ends; mere
hexagonal flakes; hexagons with a simple extension at each angle,

and hexagons with complex extensions in myriad varieties—and all are beautiful. Naturally then, hundreds of these numberless forms, as admirably photographed by that enthusiast, Mr. W. A. Bentley, of Jericho, Vermont, have been used as models in design and art. Nor is there a keener zest than Mr. Bentley's as year after year he adds pattern upon pattern to his long since marvellous collection of photomicrographs of the snow crystal.

WHY THE ATMOSPHERE AS A WHOLE NEVER IS SATURATED.

Since evaporation is continuous from much the greater portion of the surface of the earth it would seem that the atmosphere would soon become saturated throughout, and perhaps even filled everywhere with fog and cloud. But before the surface air has become approximately saturated to any considerable depth it commonly is carried to higher levels by some type of convection, and this causes it to cool, as already explained, and eventually to give up much of its moisture, generally in the condition of rain or snow. Sooner or later, however, the air out of which the precipitation falls returns to lower levels where clearly it is less humid, on the average, than when it began to ascend by the amount of water abandoned during its upward course. In short, vertical convection induces precipitation through cooling, and precipitation in turn so dries the air as to prevent it from becoming and remaining everywhere intolerably humid, as it otherwise would be.

WHY CLOUDS FLOAT.

Since water is about 800 times heavier than air one might well wonder how it is possible for a cloud, consisting of myriads of droplets, to float in a medium so light and of such slight resistance to penetration as the atmosphere. But, however imperceptible and entirely negligible the resistance of still air may be to our own movements, it is not strictly zero. In vacuo, for instance, as we know from one of the most familiar of experiments, " the farthing and the feather fall together," but more and more apart in air of increasing density. Now the total pull of a raindrop, say, causing it to fall, remains the same no matter how finely it is divided, while the amount of air disturbed, and hence the resistance and time of fall, increase with every subdivision; and since a single raindrop, one-sixth of an inch in diameter, is divisible into, or is the equivalent of, eight million average cloud droplets, it is clear

that, while the rain may descend, the cloud must settle, if it comes down at all, much more slowly.

Cloud droplets of the size just implied, that is, such that twelve hundred of them side by side make a row one inch long, do, as a matter of fact, fall through still air about eight feet per minute. Hence, where there are no rising currents, a cloud must, and does, gradually sink into the lower unsaturated air and evaporate. Clouds, however, as explained above, commonly are formed in ascending currents, and this ascent generally is distinctly greater than eight feet per minute, the rate just given of cloudfall in still air. Hence cloud is continuously formed at that level at which the rising air is cooled by its expansion to the dew-point. The droplets here formed are carried to higher levels, there evaporated or merged into raindrops, or carried away, as circumstances determine, but new droplets replacing these are as continuously being formed as fresh humid air arises to the cloud-level.

Clouds, therefore, do not even eventually fall to the earth because either they are continuously formed at the condensation level by rising currents or, on slowly sinking (eight feet per minute) to lower levels in still air, or being dragged down by descending air, are soon evaporated. In any case the cloud floats at a greater or less height and never falls precipitately to the earth as does rain.

HOW RAIN IS PRODUCED.

Few people ever ask how rain is produced. Perhaps this is because the phenomenon is too familiar to arouse one's curiosity or make him in the least inquisitive. Nevertheless, and however childish it may seem, it is both a rational question and a difficult one to answer.

The familiar, pretended answer, is, in effect, that somehow the air is cooled until condensation occurs on the various nuclei present, and that the larger of the droplets thus produced that happen to be well up in the cloud fall to lower levels, thereby encountering many other particles and through coalescence with them growing into full-sized drops. But, as implied, this explanation explains nothing. In the first place there are so many nuclei present in the atmosphere—hundreds at least, and usually thousands, to every cubic inch—that division of the condensed vapor between them leaves every one quite too minute to fall with any considerable velocity. Then, too, calculation shows that if a

particle should fall, in the manner supposed, through a cloud even a mile thick and pick up everything in its path it still would be a small drop. That is, rain is not formed in this simple manner, as is also obvious from the fact that a cloud may last for many hours without giving any rain whatever.

The actual processes in the formation of rain seem to be:

1. For some reason, such as surface heating, a mountain in the wind's path, or convergence of different currents, the surface air is forced up to considerable heights; during which rise it does work—gives up energy—by expansion against the surrounding pressure and thereby cools.

2. As soon as the dew-point is passed condensation begins on the innumerable nuclei present and a cloud is formed, the particles of which, being heavier than equal volumes of air, slowly fall with reference to the atmosphere itself. That is, the rising current passes by the cloud particles to a greater or less extent however high they may be carried.

3. The lower cloud particles filter the air rising through them and thereby more or less clean it of dust motes and other nuclei. Hence the droplets formed in the rising air after this filtration grow much faster, being relatively few, than they otherwise would.

4. Presently many of the larger droplets coalesce and thus become heavy enough to fall against the rising current. Nor, indeed, can they fall (reach lower levels) until by condensation, or coalescence, or both, they have attained a certain minimum size determined by the vertical velocity of the air in which they happen to be.

In short, a rising current, essential to any considerable condensation, that sustains, or even carries higher, cloud droplets until they have grown to falling size, and the automatic filtering of the ascending air by the cloud formed in it (which filtering restricts further condensation to comparatively few particles and thus insures their rapid growth), appear to be necessary and sufficient to account for the formation of rain.

5. Most of the drops, as they emerge from a cloud, are likely to have substantially the same size, namely, that which is just sufficient to overcome the upward movement of the air in which they were formed. Now, drops of the same size fall with the same speed, hence any two that happen to be close together are likely to remain so much longer than drops of unequal size and

thereby have more chances of union through fortuitous disturbances. Furthermore, when falling drops are side by side the air tends to push them together just as passing boats are forced toward each other. Clearly, though, this pressure has time to bring closely neighboring drops into actual contact only when they fall with the same, or very nearly the same speed. From these considerations it seems that the smallest drops, size 1, say, should unite to form size 2, and size 2 unite with each other to form size 4, rather than with size 1 to form size 3, and so on, doubling at each union. Hence we should expect more drops having the weights 1, 2, 4, 8, ... than any intermediate values, and this expectation has been fully verified by observations on all sorts of rains.

THE MEASURING OF CLOUD HEIGHTS.

It is always interesting and sometimes very useful to know the heights of the clouds, or, to be more exact, the heights of their bases—useful, frequently, to the aviator to whom very low clouds may be a danger and certainly a nuisance, and useful as an aid in forecasting the local weather for the next few hours.

There are several methods of determining the heights of clouds as accurately as ever is necessary. Indeed, under favorable circumstances, the error may not be more than a few feet.

1. The aviator, for instance, can take the reading, corrected if necessary, of his altimeter the instant he climbs into the base of a cloud.

2. A pilot balloon (small free balloon without instruments) may be observed from two stations a mile, say, apart, and its exact direction from each station, both horizontal and vertical, noted as it disappears into a cloud base. From these directions, which can be determined very accurately with suitable theodolites, and from the known distance between the two observing stations and the height of either above the other, the cloud height is readily obtained by a simple trigonometrical calculation.

3. Any definite spot on the base of a cloud may be simultaneously observed (triangulated, to be exact) from the two stations and its height calculated from the data thus obtained, precisely as in the case of the pilot balloon. The observations of course may be either visual or photographic; the latter, if well done, generally being the better since it affords opportunity for

detailed study and independent measurements on many different points.

4. The angular altitude of a kite and the length of wire out, at the time it enters a cloud base, also furnish a fair means of computing the desired height.

5. The exact time of disappearance of a kite up into a cloud may be noted, and the height of the kite at that instant, and hence also of the cloud, determined by subsequent examination of the temperature and pressure records on the kite instruments.

6. The level of storm-clouds, or low clouds at the time of strong winds, and of ordinary cumuli, can be tolerably closely computed from the current values of the temperature and humidity.

The above are by no means all the possible ways of measureing the heights of clouds, but they are the more accurate, and the ones most commonly practised.

WHY THE BASE OF A GIVEN CLOUD, OR CLOUD SYSTEM, HAS EVERYWHERE NEARLY THE SAME HEIGHT.

One of the most interesting and significant things learned from cloud measurements is the fact that the base of any cloud sheet, that is, a particular sheet at a particular time, whether continuous or broken and scattered, is everywhere at about the same level. The reasons for this are very simple: (*a*) Since the temperature and humidity of the air at any given time are nearly the same at neighboring places over a considerable area, the height throughout such region is approximately constant at which rising air will have cooled to the dew-point and cloud begun to form. Hence the base levels of a series of detached cumulus clouds are about the same. (*b*) Since rising air ascends until, by expansion, it has cooled to the temperature of the then surrounding air, at which level it spreads out and drifts away with the general circulation, and as convection, whatever its cause, applies to air of all degrees of humidity, and occurs at different times and all manner of places, it follows that the atmosphere is always more or less stratified in respect to its water vapor. In general, therefore, clouds must also form in these layers. There may be, and aften are, two or more cloud layers at the same time at different levels, but a cloud filling the whole depth of the atmosphere, or even a layer five or six miles thick, is not to be

expected, nor is any such layer of considerable extent often if ever formed.

LEVELS OF MAXIMUM CLOUDINESS.

Since several types of clouds occur at various elevations, and since no level, from the surface of the earth up to the highest cirrus, is free from condensation, it might seem that clouds are as likely to have one height as another throughout their possible range. However, it is certain that there are levels of maximum and minimum cloud frequency, even though it may not be as easy to prove some of them by direct observation owing to the prevalence of lower clouds. The more important levels of maximum cloudiness are:

Fog Level.—As every one knows, a fog, whatever its depth, from a mere gauzy veil to the deepest and densest layer, is a cloud on the earth. Obviously, therefore, the surface of the earth itself is a level of maximum cloudiness.

Cumulus Level.—Since evaporation tends all the time to saturate the atmosphere, and since humidity is held down by convectional condensation, and, further, since, over extensive areas, convection is roughly the same most of the time through an entire season, it follows that the ordinary rain cloud, and the common cumulus cloud, must have a roughly standard base level at a moderate elevation. This level, therefore, say 4000 feet above the surface, is also a level of maximum cloudiness.

Alto-cumulus Level.—The strong convection common to dry summer weather often produces small cumulus clouds at considerable heights—frequently two to two and one-half miles above the surface. Furthermore, during the average thunderstorm a great deal of humidity is urged up to roughly this same level, and there spread out into a wide layer by the swifter winds of that height. Subsequent convections in this layer often induce many small cumuli. For both reasons, therefore, this level, known as the alto-cumulus level, is likewise one of maximum frequency of cloud.

Cirro-stratus Level.—The topmost portions of the clouds in a cyclonic, or general, rain, are carried forward over very extensive areas by probably the swiftest winds of the entire atmosphere. Hence this level, roughly five miles above the surface, is also one of maximum cloud frequency, or at least of cloud observation.

Cirrus Level.—Rising masses of air can not ascend, for reasons well known, beyond the level of the highest cirrus clouds, that is, in middle latitudes, above an elevation of about six miles. Any air that reaches this level necessarily spreads out in an extensive sheet or layer in which, under favorable conditions, condensation occurs in the form of fine snow crystals. Hence this ultimate level of the ascending air, at which its horizontal spread is great, is also one of maximum cloud extent.

LEVELS OF MINIMUM CLOUDINESS.

If there are different levels of maximum cloudiness, it follows that between each two such adjacent levels there must be a level of minimum cloudiness. However, there is nothing of particular interest about any of these intermediate levels.

Why There Are no Clouds above the High Cirrus.—The region above the high cirrus also is one of minimum cloudiness. In fact clouds do not occur in that region at all, and the reason is as follows:

There clearly is some temperature (actually about 60 degrees Fahrenheit below zero) at which each portion of the high atmosphere must lose as much heat by radiation as it gains, and this is the lowest temperature to which the free air can cool. This temperature is reached, in middle latitudes, at about six to seven miles above sea-level. Hence this is the limit of vertical convection— for higher convection would mean lower temperatures—and the maximum height, therefore, to which water vapor is carried. Of course some water vapor reaches greater heights by the slow process of diffusion, but all of this region is subject to frequent temperature changes just as is the lower atmosphere, hence as soon as any appreciable amount of vapor diffuses to a higher level than that of the average cirrus it is frozen out in invisibly small amounts and the whole of the upper air thereby kept too dry for the formation of even the thinnest clouds.

RELATION OF CLOUD HEIGHTS TO SEASON.

Clouds generally are lower during winter than during summer. This is because the relative humidity is higher, or the atmosphere more nearly saturated, during the colder season than during the warmer. And this condition, in turn, is owing largely to the fact that vertical convection, which is the chief cause of rain and hence

the chief drying agency of the air, is most active during summer, when the surface of the earth is strongly heated.

RELATION OF CLOUD HEIGHTS TO LATITUDE.

Just as clouds generally are higher in summer and lower in winter, so, too, and for the same reason, clouds commonly are highest in equatorial regions and gradually descend with increase of latitude to their lowest level in polar regions.

RELATION OF TYPE OF CLOUD TO THE SEASON.

As just explained, vertical convection, which is due largely to surface heating, is much stronger during summer than during winter. Hence the cumulus or woolpack cloud, a product of local convection, is characteristic of warm summer days, while the low stratus or layer cloud is equally characteristic of the winter season.

RELATION OF TYPE OF CLOUD TO LATITUDE.

For the same reason that the prevailing type of cloud varies with the season, it also varies with latitude. That is, in tropical regions, where vertical convection is strong, the cumulus cloud is very common, whereas, in the high latitude regions, where convection is feeble, it is unusual. Here the prevailing cloud is of the stratus or layer type.

CLOUD THICKNESS.

The thickness of clouds varies from all but zero in the case of faint cirrus, and vanishing wisps and flecks of any other type, up to the ten miles or more of the deepest tropical cumulus. Habitually, however, the high cirrus, only a few hundred feet thick, is the thinnest of clouds; the cumulus, especially when the seat of a hail storm, is the thickest—often several miles deep. The common nimbus cloud, from which rain often falls all day, varies in thickness from, say, 500 feet, up to four or five miles. Its average thickness, however, appears to be, roughly, half a mile. All other types of clouds generally are intermediate in thickness between the cirrus and the nimbus, averaging, perhaps, 500 to 1500 feet.

CLOUD VELOCITY.

The direction and speed of travel of clouds can be determined in several ways, most of which involve triangulation of the kind

used by surveyors and geologists. In the great majority of cases the velocity of a cloud is that of the air in which it happens to be. In a few cases, however, the movement of the cloud is not that of its enveloping atmosphere. Thus the cloud that forms along the crest of a mountain is as stationary as a waterfall, and, like the waterfall, is continually renewed by fresh material. No matter how swift the current, the fall remains fixed, and however strong the wind over the mountain, cloud is formed in it as soon as it reaches a particular altitude, determined by the humidity and temperature, and evaporated as it is drifted beyond and to lower levels. The crest cloud, therefore, being always stationary, can not be used in measuring wind velocity. Neither can the riffle cloud, the lenticular cloud, nor the banner cloud, and for the same reason— all are stationary whatever the wind velocity.

Neither can the velocity of the wind be determined by the movement of the parallel rolls of the windrow or billow cloud. These clouds rest on the crests of air waves which are caused by the flow of one wind sheet over another. The velocity of these waves, and hence of the clouds that crest them, is intermediate between that of the two sheets, and therefore does not measure the actual velocity of either.

In the great majority of cases though, that is, with the above exceptions, clouds do move strictly with the enveloping air. Hence, though everywhere blowing, in the course of time, from all directions—boxing the compass, as the mariner says—in the tropics they are nearly always from easterly points, northeast to southeast, and in middle latitudes prevailingly from westerly regions.

Their average velocity, *when moving in their prevailing direction,* increases with height at approximately the same proportion that the density of the atmosphere decreases, that is, at such a rate that the product of the velocity (cloud or wind) by the density of the air is a constant.

VARIATION OF CLOUDINESS WITH LATITUDE.

As is well known, the amount of cloudiness varies greatly in different parts of the world. In some places it would be perfectly safe, following the example of the Yuma hotel, to advertise free meals for every day the sun does not shine; and equally safe in others to make a similar offer for every whole day that it does. Apart from such obvious causes of cloud variation as direction of

the wind, particularly onshore and offshore, elevation, temperature, *et cetera,* there is also a well-marked latitude effect. Thus, in the equatorial regions, where convection is most active, nearly 60 per cent., on the average, of the sky is clouded; around latitude 30 degrees, both north and south, or along the great belts of high pressure, and over the principal arid regions, the average cloudiness falls to the minimum value of 40 to 45 per cent.; while in the neighborhood of the polar regions it becomes 60 to 75 per cent. All these are only average values for the respective latitudes. The cloudiness of individual places covers a much wider variation.

CLOUD SPLENDORS.

Crepuscular Rays.—Everyone is familiar with the beautiful phenomenon of the " sun drawing water " (Fig. 36)—sunbeams, that, finding their way through rifts in the clouds, are rendered luminous by the dust in their paths. Many people seem to consider this splendor an excellent weather sign: Some insisting that it foretells rain, while others as strongly claim it indicates continued fair. As a matter of fact, it has no significance either way, hence its excellence as a bone of contention.

When there are a number of such rifts the beams of light seem to radiate from the sun like spokes from the hub of a great wheel, or like ribs from the pivot of a giant fan. However, they are practically parallel, for the sun, from which they all come, is 93,000,000 miles away. The seeming divergence is only a perspective illusion, the same as that which makes any long, straight, parallel lines, such, for instance, as the rails on a straight, level track of railway, appear to come closer and closer together with increase of distance.

Lightning.—Few things in all nature so widely range our sensibilities, from thrills of joy over the exquisitely beautiful to abject terror in the face of imminent death, as does the lightning's flash from the heart of the thunder cloud.

The story of this wonder meteor—how Franklin showed it to be a form of electric discharge; how, as explained by Simpson, charge after charge is obtained within the cloud; what curious freaks it plays and marvellous things it does—is delightful in every detail, but far too long to include here, for, after all, lightning, whatever its interest and importance, is only a cloud incident.

When the storm is close by it is easy to see that lightning con-

sists of one or more sinuous (not zigzag, as the artist paints it) lines or streaks of vivid white or pink. Often there is one main

Fig. 36.
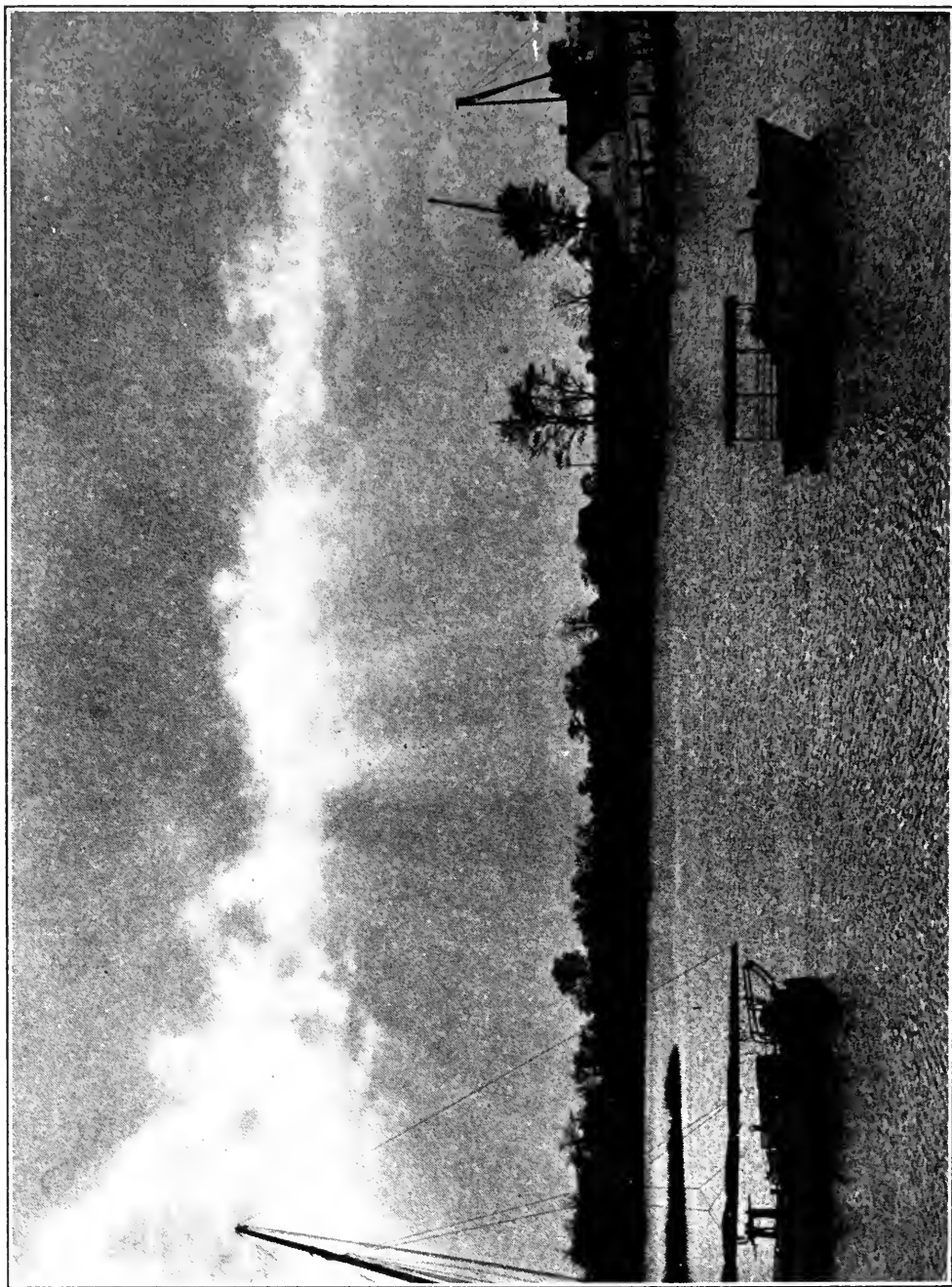
Crepuscular rays, seen on the Potomac River. (P. E. Budlong, photo.)

trunk with a number of branches, all occurring at the same instant, while at other times there are two or more simultaneous, disconnected streaks. Frequently the discharge, instead of being all

at once, continues flickering; and, on rare occasions, even stationary, like a glowing wire, during a whole second, or more.

The autobiography of a typical flash of lightning is jointly given by Fig. 117, *Physics of the Air,* obtained with a stationary camera, and Fig. 118, *Physics of the Air,* taken at the same time with a rotating camera, and showing a number of separate discharges which together constituted the flickering whole, each faithfully following the path ionized by the initial member of the series.

The Rainbow.—Unlike the phenomenon of lightning the rainbow is all beauty and splendor, with nothing whatever of the appalling—save alone to the physicist who undertakes to explain fully and clearly its every detail, a most difficult task. Perhaps this assertion may seem strange when so many text-books, even some that are quite elementary, profess to explain the rainbow so simply that a child can understand it, but in this particular nearly all these books have the same fault: They " explain " beautifully that which does not occur and leave unexplained that which does.

The ordinary rainbow seen in a sheet of water drops—rain, spray, fog—is a group of circular or nearly circular arcs of colors whose common centre is on the extension, in the direction of the observer's shadow, of the straight line connecting his eye with the luminous source, which, as everyone knows, is nearly always the sun, but not quite, for once in a while the moon too produces a very pretty bow.

Frequently there are two entirely different bows. The inner one, known as the *primary,* with red outer border of about 42 degrees radius, and blue to violet inner border, is much brighter than the larger, or *secondary* bow, of about 50 degrees inner radius, and whose colors occur in the reverse order of those of the primary bow. In addition to these two conspicuous bows one can often see from one to, rarely, half a dozen parallel, colored arcs just inside the primary bow, and a smaller number just outside the secondary bow. These are known as the *supernumerary* bows. Most of these phenomena are shown in Fig. 37, copied, by kind permission, from a remarkably fine picture taken by Mr. G. A. Clarke, of Aberdeen, Scotland.

A careful observer will soon see that there is less light (that the clouds look darker) between the two bows than outside the secondary or within the primary; that the colors seen are not

always the same: that the band of any given color varies in angular width, even, occasionally, from place to place in the same bow;

Fig. 37.
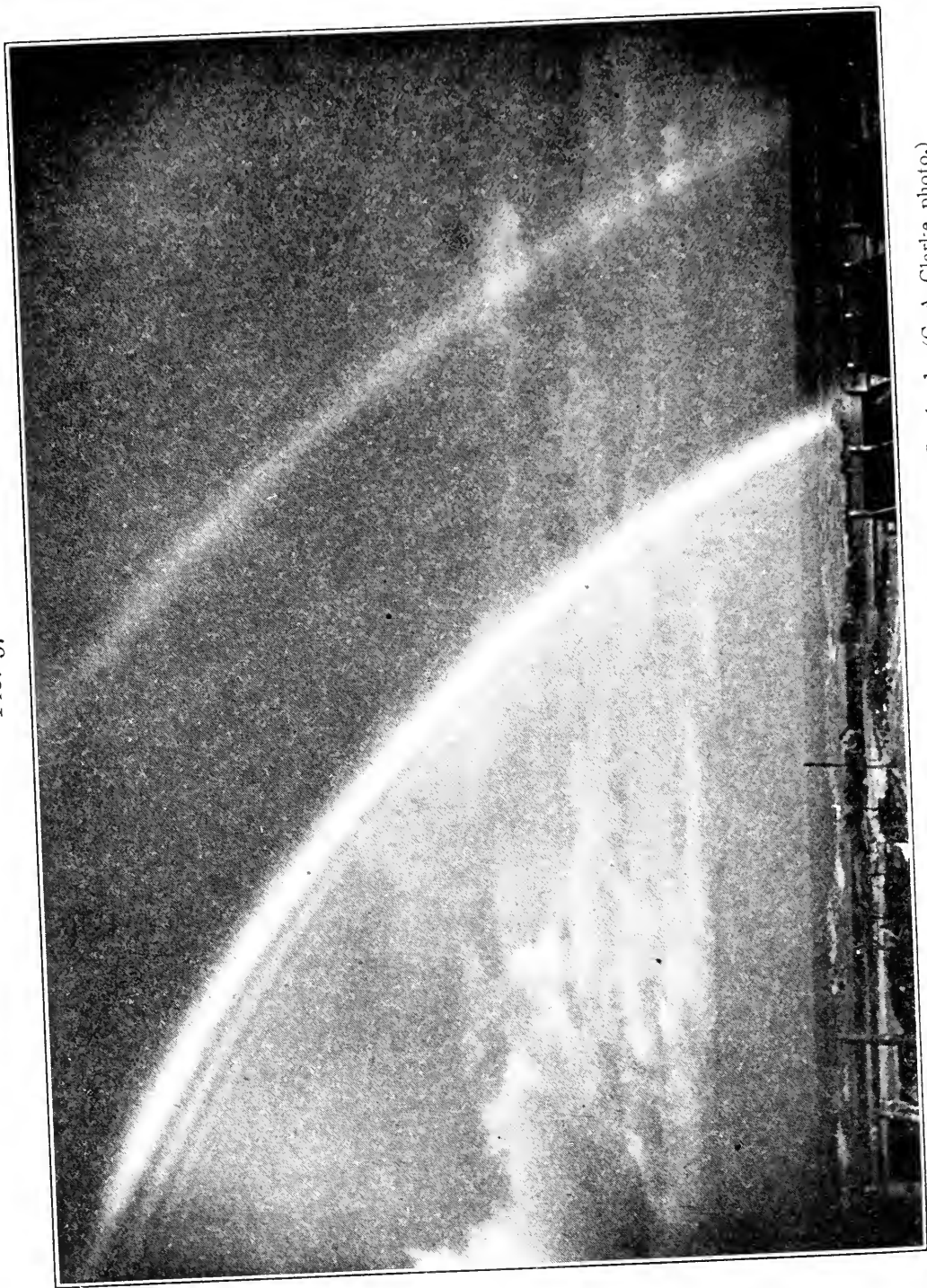
Rainbow, primary, secondary and supernumeraries; seen at Aberdeen, Scotland. (G. A. Clarke, photo.)

and that the purity of the colors varies from time to time. As one would naturally suspect, all, or nearly all, these differences

depend on the size of the droplets. The greatest contrast, perhaps, is between the brilliant rainbow of the retreating shower and that ill-defined, faintly tinged bow one sometimes sees on a sheet of fog.

The Halo.—As must be obvious to anyone, the cirrus and other very cold clouds nearly always consist of ice crystals. These reflect some of the light that falls upon them; and some of it they transmit, bent, or refracted, as we say, out of its course and split up into all its color, but always with the red nearest to the source of light. Both the refracted and the reflected light produce various bright patterns properly known as halos.

By refraction we get: The very common ring of 22 degrees radius about the sun or moon (Fig. 9) ; the less frequent ring of 46 degrees radius; the occasional brilliantly colored arc that has its centre directly overhead and its convex side next the sun; and, rarely, numerous other splotches and arcs, all more or less distinctly colored, and things of beauty and interest.

By reflection, on the other hand, we get only white or color-less figures; chiefly, the parhelic circle, Fig. 9, that passes through the sun and is parallel to the horizon; and a pillar of light that rises straight up through the sun, much as would its reflection in rippled water if stood on end.

The Corona.—Thin clouds of water droplets also produce beautiful colored rings about the sun and moon, but usually much smaller than the circles formed by refraction through snow crystals, and with their colors in reverse order, that is, with the red farthest from the source of light, instead of nearest to it. These rings, known as coronas, are owing to what the physicist calls diffraction, or, in this case, the bending of the light around the droplets into their shadows. They are most frequently seen about the moon, but may be seen even more brilliantly, occasionally in a widening series of two or three repetitions of the colors, about the sun, if one will use dark glasses to cut down the glare.

Fig. 38, from a drawing by Mr. G. A. Clarke, of Aberdeen, Scotland, shows a magnificent corona and also contains other phenomena observed by him at that place on June 13, 1921. These were: (*a*) The slightly veiled image of the sun; (*b*) an aureole of faintly colored light close to the sun; (*c*) a triple corona in which the radii of the red or outer borders of the three rings were

about 6 degrees, 10 degrees, and 16 degrees, respectively; (*d*) iridescence (see below) merged with and extending beyond a portion of the outer coronal ring; (*e*) portions of a fine halo of 22 degrees radius, produced by a background of thin cirro-stratus.

Cloud Iridescence.—Unquestionably the most beautiful thing in all the heavens is a magnificent display of iridescent clouds—

Fig. 38.
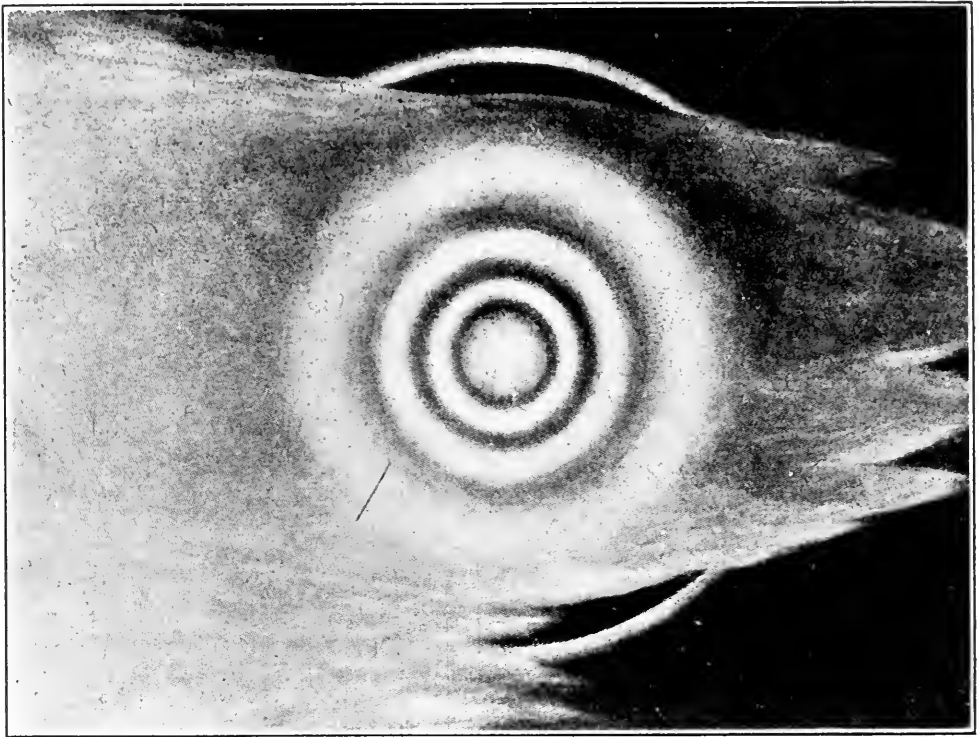
Corona, triple, and 22° halo, drawn by G. A. Clarke, Aberdeen, Scotland

numerous splotches among the cirro-cumuli, or other high type, and borders of thin lenticular alto-strati and alto-cumuli, of gorgeous opalescent rose pinks, emerald greens, and other colors, randomly mixed and covering a large part of the sky 15 to 30 degrees from the sun.

It can be fully explained (being only fragments of giant coronas due to unusually small droplets), but only in the language of the physicist and symbols of the mathematician. Its beauty, however, can be enjoyed by all, and whoever looks at the heavens for anything should watch most frequently and carefully for the glorious apparition of the iridescent cloud.

CLOUDS AS WEATHER SIGNS.

Since the height, extent and shape of clouds depend upon the humidity, temperature and motion of the atmosphere it is obvious that they often may furnish helpful hints of the coming weather. Thus, thin cirrus clouds, when not increasing in extent nor growing denser, indicate fair weather for at least twenty-four hours; and the same is true of the alto-cumuli. In general

> " The higher the clouds, the finer the weather."

On the other hand, when the cirrus grows denser, and when the sky is covered with cirro-cumuli, rain within twenty-four hours is likely.

> " Mackerel scales and mares' tails
> Make lofty ships carry low sails."

Also, when large cumuli develop in the forenoon, there probably will be local thundershowers in the afternoon.

> " In the morning mountains,
> In the evening fountains."

Again, when two or more layers of cloud are moving in different directions, foul weather is almost certain to occur very soon. In short, if one may coin a " proverb,"

> Whene'er the clouds do weave
> 'Twill storm before they leave.

Clouds of the lower and intermediate levels from north to west usually imply fair weather for a day or two; clouds from east to south generally mean rain within twenty-four hours. (This is for most of the temperate regions of the northern hemisphere; for the southern hemisphere, write north for south, and south for north.)

> " When the carry [current of clouds] goes west,
> Gude weather is past;
> When the carry goes east
> Gude weather comes nest."

Fog clearing up early means a fair day; fog persisting implies that there probably will be rain later in the day, or during the coming night. As the proverb puts it:

> " Mists dispersing on the plain,
> Scatter away the clouds and rain;
> But when they hang on the mountain tops
> They'll soon descend in copious drops."

BIBLIOGRAPHY

Anyone especially interested in clouds will find several, if not all, of the following worth reading:

Ley, W. Clement, "Cloudland," London, 1894, xiv, 208 pp.; 8vo. (A study on the structure and characters of the clouds.)

Clayton, H. Helm, "Observations Made at the Blue Hill Meterological Observatory—Discussions of the Cloud Observations," Cambridge, 1896, 269–500 pp.; 4to. *(Annals of the Astronomical Observatory of Harvard College,* v. 30, pt. 4.)

Clayden, Arthur W., " Cloud Studies," London, 1905, xiii, 184 pp.; 8vo.

Vincent, J., "Atlas des Nuages," Bruxelles, 1907, 29 pp.; folio. *(Annales de l'Observatoire Royale de Belgique, Nouvelle Série. Annales Météorologiques.)*

Loisel, Julien, "Atlas Photographique des Nuages," 2 ed., Paris, 1912, folio. (20 Cloud Photographs.)

Neuhaus, E., " Die Wolken," Zurich, 1914, 48 pp.; 30 cloud photographs, 4to. (Use of clouds in local forecasting.)

Taffara, L., " Le Nubi," Rome, 1917, 67 pp.; 4to. (50 good cloud photographs; details of cloud observing and photographing.)

Clarke, G. A., " Clouds," London, 1920, xvi, 136 pp., 12mo. (Forms, causes, distribution, and weather significance; many excellent illustrations.)

Echoes from the Past.—The Franklin Institute has recently received by gift a copy of a volume of Berzelius' " Lehrbuch der Chemie," dated 1836. In discussing the use and value of the chemical symbols (which were introduced by Berzelius) reference is made to the fact that a French work on mineralogy lately published had used symbols derived from the French names of the common elements instead of from the Latin names, as Berzelius did in order to make them international. As a protest against this " national vanity," the author quotes from a speech Davy made, as president of the Royal Society, in presenting the Coplay medal to Arago, for discoveries in magnetism. Davy said " Science, like the nature to which it belongs, is neither limited by time nor space; it belongs to the world and is of no country and of no age."

In connection with this statement is a collection of replies to some objections that have been made to the symbols. They were declared obscure, misleading and purposeless. It was said that they are displeasing to mathematicians, inasmuch as the exponent attached to the symbols has a higher value in mathematical formulæ than in the chemical, and the mathematician should have the right of way in such matters. It also objected that in Greek and Russian P is read as R. These objections were mostly ignored, but early in the application of symbols the objection in regard to the significance of the exponents was met by writing them as inferiors, a system which has been universally adopted except by French chemists and it is to be hoped that they will fall in line soon.   H. L.

ELECTRIC RAILWAY DISTURBANCES AND THE DETECTION OF PASSING ELECTRIC TRAINS BY MEANS OF A GALVANOMETER.*

BY

E. S. BIELER, M.Sc.

Exhibition of 1851, Scholar of McGill University, Montreal.

DURING a series of experiments carried out in the Macdonald Physics Building, McGill University, on the currents induced in a conductor by the passage of a sphere of magnetic material over it,[1] considerable trouble was at first experienced due to disturbances apparently connected with the passage of electric cars in the neighborhood.

The apparatus used consisted of a coil of 200 turns of copper wire wound on a square frame of 125 cm. side, and connected to a sensitive reflecting galvanometer of the moving coil type. The galvanometer deflections were registered photographically on a roll of bromide paper actuated by clock-work. With a total external resistance of 224 ohms, equal to the critical damping resistance of the galvanometer, a sensitivity of 1.56 mm. per microvolt was obtained.

When the coil was placed with its plane horizontal, a continual motion of the galvanometer spot was observed. This attained a maximum amplitude at the rush hour on the street car system, and ceased almost completely about 2 A. M., Standard Time, when the street car service is practically suspended (See Fig. 1). On the whole, the disturbances agreed well with the supposition that they were due to currents in some way connected with the operation of the street cars in the neighborhood. These disturbances could be almost completely balanced out by placing in series with the coil a large loop of wire of three turns enclosing a total area equal to the combined area of the turns of the coil. The fact that this was possible indicates that the source of the disturbance must be at a distance from the apparatus, fairly large compared with the linear dimensions of the loop, and shows defi-

---

[1] E. S. Bieler, *Proc. Roy. Soc.,* vol. c, p. 50 (1921).

Fig. 1.
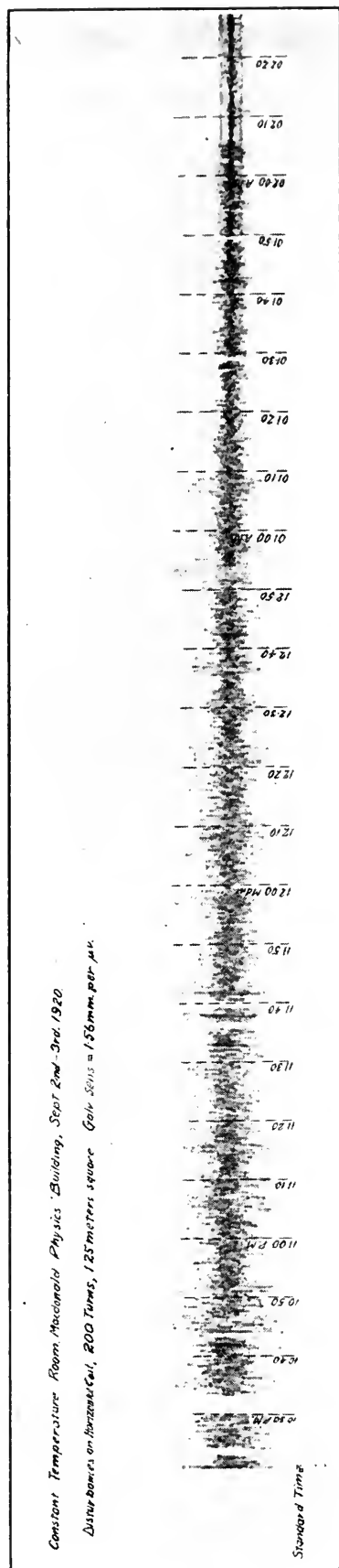
nitely that it cannot be either inside the building or in its immediate neighborhood.

When the coil was placed in a vertical plane, on the other hand, there was practically no disturbance, and it was not necessary to use any balancing loop. This was rather unexpected, as the circuit composed of the trolley wire and the rails ought to have an appreciable mutual induction with any circuit in a vertical plane in its neighborhood.

At the time when these observations were made Doctor Eve had been supervising some experiments to determine whether the passage of electric trains through the C.N.R. tunnel under Mount Royal produced any mechanical disturbance in the university buildings straight above it. He suggested that the galvanometer and coil should be set up in the basement of the library, 60 ft. directly above the axis of the tunnel, in order to detect any electrical disturbance.

The coil was accordingly placed with its plane in the axis of the tunnel, and the deflections of the galvanometer registered in the usual manner. In addition to a continual disturbance of small amplitude, large deflections were obtained, which coincided exactly with the times of trains. One of the records obtained is shown in Fig. 2. The times at which trains were heard to pass

Fig. 2.

McGill Library, Aug, 31st, 1920, Record of Disturbances on Vertical Coil
Coil - 200 Turns, 1·25 meters square, Galvr.- Sens, 1·56mm, per μv.

Fig. 3.

McGill Library, Sept 1st 2nd 1920, Disturbances on Vertical Coil

Coil, 200 Turns, 1·25m square Galv. Sens 1·56mm per μv
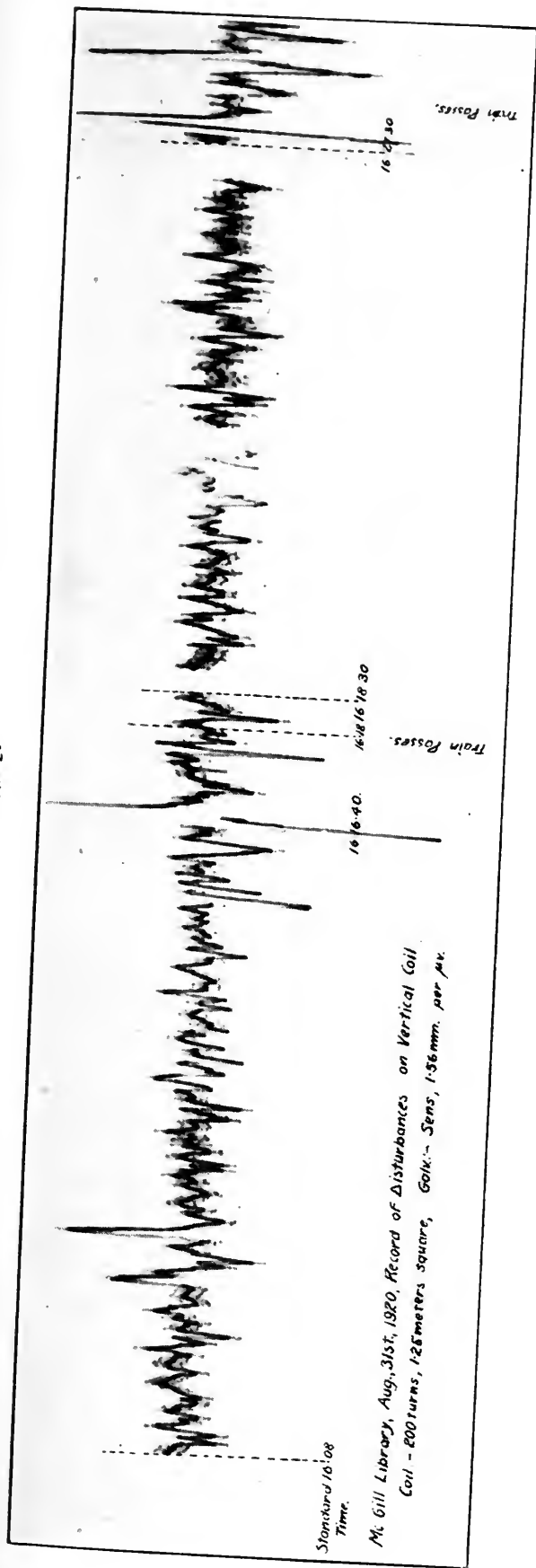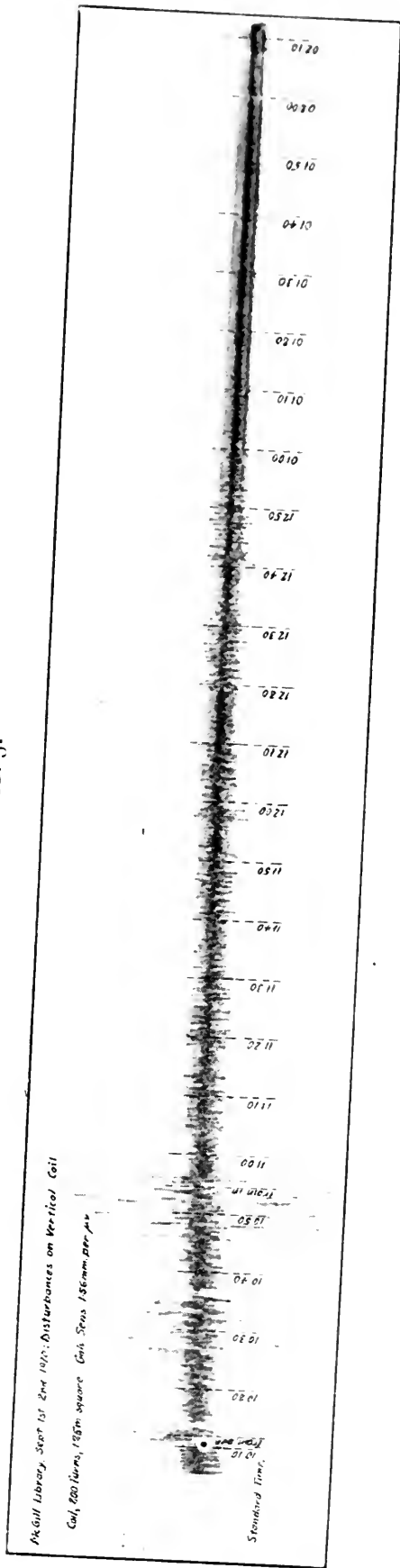
during the period correspond with the two large disturbances.
Fig. 3 shows a record taken over a longer period with a reduced
time scale.   Two of the large deflections correspond with the
only two trains during the period.   The disturbance at 10.30 P. M.
is probably connected with switching operations in the station.

FIG. 4.
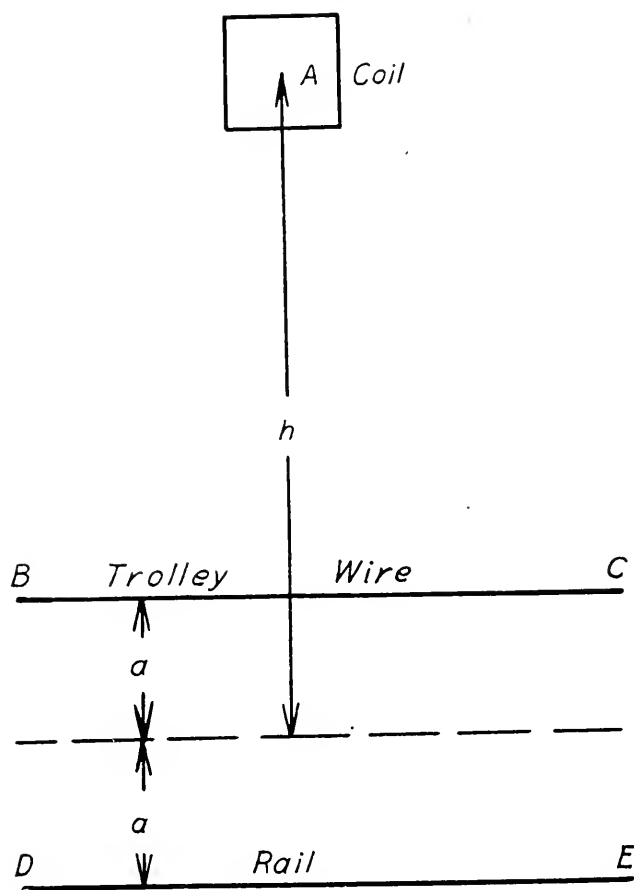
It will now be shown that the observed disturbances are of
the order to be expected.

In Fig. 4, let A represent the coil, BC the trolley wire, and DE
the rails of the electric railway in the tunnel.

Let S be the area of one turn of the coil, n the number of
turns, $2a$ the height of the trolley wire above the rails, and h the
height of the coil above a line midway between the rails and the
trolley wire.

If i is the current in the trolley wire at any time, the field at

A due to i and the return current through the rails is equal to

$$\frac{2i}{10\,(h-a)} - \frac{2i}{10\,(h+a)} = \frac{4ai}{10\,(h^2-a^2)}$$

If N is the total number of interlinkages between the tubes of induction due to i and the turns of the coil, the emf induced in the coil when the current changes is given by

$$E = -\frac{dN}{dt} \times 10^{-8} \text{ volts}$$

$$= -\frac{4\,naS}{h^2-a^2} \cdot \frac{di}{dt} \times 10^{-9} \text{ volts}$$

Now, the deflections obtained are of the order of 5 cm. and E is therefore of the order of 30 microvolts. Also, the side of coil is 125 cm., and the approximate values of h and a are 2000 cm. and 200 cm. respectively.

Substituting these values in the above equation, and solving for $\frac{di}{dt}$, we obtain,

$$\frac{di}{dt} = 50 \text{ amperes per second,}$$

approximately.

This is of the right order for the rate of change of current taken by an electric locomotive when starting or stopping.

A similar calculation can be made in the case of the street car disturbances mentioned above.

If $2a$ is as before the height of the trolley wire above the rails, and d the horizontal distance between the coil and the line, it is easily shown that the emf produced in the coil when set in a vertical plane parallel to the line is given by

$$E = -\frac{4\,naS}{d^2+a^2} \cdot \frac{di}{dt} \times 10^{-9} \text{ volts}$$

The distance from the nearest street car line was about 300 yards. Even if we assume for E a value as large as 50 amperes per second, the value of E obtained is only 0.14 microvolt. This would give a deflection of 0.2 mm. approximately.

It is easily seen that current variations in a circuit composed of the trolley wire and the rails of a street car line can induce no emf in a horizontal coil at their own level.

We must conclude therefore that the disturbances mentioned in the beginning of this paper cannot be caused directly by the

currents in the trolley wires and rails, but must be due to large currents flowing at no great distance from the building, approximately at the level of the laboratory where the experiments were conducted. This may be due to a power line connecting the street-railway power house to a distant part of the system, or to a return current along some metal pipe-line.

A current variation of 50 amperes per second in a single conductor 200 metres from the building or a smaller current at a proportionally smaller distance would give deflections of the order observed.

The departure of the writer for England made it impossible for him to pursue these experiments further, and to locate the exact cause of these disturbances. The results obtained are communicated with the hope that they will be of some use, in view of the ever increasing number of electric traction lines, and the trouble they must necessarily cause to all who attempt delicate electrical measurements in their neighborhood.

The author's thanks are due to Dr. A. S. Eve for his kind interest in these experiments.

CAVENDISH LABORATORY,
    CAMBRIDGE, ENGLAND,
        December, 1921.

New Method of Hydrogenation.—GRANICHSTÄDTEN and SITTIG describe, in *Giornale di Chimica,* the use of a nickel-magnesium silicate as a catalyst of high power in hydrogenation, oils acquiring an unusual degree of whiteness at not above 40° C. With most methods now in use dark oils must be previously bleached if desired to be of good color, but with the new process this bleaching is not required. The catalyst is prepared by precipitation so as to secure as uniform a product as possible. The procedure promises to be widely used and is to be covered by patents.—*Chem. News.*

                                                 H. L.

Composition of a South American Copper Axe Head.—A. K. GOAD and E. K. RIDEAL (*Analyst,* 1921, xlvi, 490) have analyzed an axe head which had belonged to an Inca Indian. It contained 96.44 per cent. copper, 3.44 per cent. zinc, 0.09 per cent. iron, and traces of silica; tin, lead, and nickel were absent. These results indicate that the axe head was composed of brass and not of copper, and that the aborigines had a knowledge of brass.

                                               J. S. H.

NOTES FROM THE U. S. BUREAU OF STANDARDS.*

AN INVESTIGATION OF OXYACETYLENE WELDING AND CUTTING BLOWPIPES WITH SPECIAL REFERENCE TO THEIR ECONOMY IN OPERATION, SAFETY, AND DESIGN.[1]

By Robert S. Johnston.

[ABSTRACT.]

At the request of the Standardization Section, Purchase Branch, Purchase, Storage, and Traffic Division of the War Department, the Bureau conducted an investigation of the operation, efficiency and safety of oxyacetylene welding and cutting blowpipes. Apparatus from fourteen different manufacturers were submitted to test. The tests were decided upon after a careful survey had been made of the technical literature on the subject and a thorough study made of the various operations in which these blowpipes are used. Suggestions for methods of tests were also secured from the manufacturers.

All blowpipes were submitted to a standard series of tests which were developed with the idea of minimizing the personal equation of the operator and securing data that was representative only of the blowpipe itself. In order to accomplish this result a rather elaborate testing equipment consisting of a weighing system, a gage-board equipment, welding table, cutting table, and safety and flashback testing apparatus was designed and used throughout the investigation.

The weighing system was used to determine the amount of gas consumed in any blowpipe operation, the process consisting in determining the loss of weight of banked tanks of oxygen and acetylene. In order to transfer the loss of weight into cubic feet of oxygen and acetylene consumed, special studies of the density of oxygen and acetylene were made. The gage-board system comprised a flow meter designed and calibrated for this investigation which was used to furnish a check upon the quantity of gas consumed in the welding and cutting operations and also to secure

---

data that would show the fluctuation of gas volumes used at different periods of time during a test.

Special care was taken to furnish the gas delivered to the blowpipes at the pressure specified by the manufacturers. To accomplish this, special compound manometers were designed and used throughout the investigation, Bourdon tube gages being only used as check apparatus. Besides observational data of the gas volume being consumed as indicated by flow-meter differential manometers and the pressures delivered to the blowpipes, autographic recording gages were also installed to secure graphical representation of the pressure fluctuations.

All welding blowpipes were submitted to welding tests on $\frac{1}{2}$ in. and $\frac{3}{4}$ in. metal. The operation of the blowpipe, however, was necessarily performed by experienced operators. For the cutting tests the blowpipes were mechanically guided and controlled so that practically all personal equation of the operator was eliminated. During the cutting tests the blowpipes were operated at the maximum speed at which they would cut metal of specified thickness. One-half in., 2 in., 6 in., and 10 in. metal were used in the cutting tests.

A further series of tests was made to determine the freedom from flashback and safety of operation of the various welding blowpipes.

The results of the initial series of tests carried out on the welding blowpipes indicated that there were some phenomena in connection with the operation of a welding blowpipe that were not understood. A very thorough study of the design of the various welding blowpipes was therefore made, and certain conclusions relative to the cause of the inconsistencies in action noticed arrived at. A supplementary series of tests was then carried on to prove the correctness of these conclusions. From this secondary investigation it is shown that the proper principles upon which the design of oxyacetylene welding blowpipes should be based were probably not fully realized. The results of this entire investigation may be summarized as follows:

For the Cutting Blowpipes.

1. There is to-day no generally accepted theory for proportioning, for the cutting of metal of various thicknesses, the volume

and velocity of the issuing cutting jet, with the result that none of the apparatus submitted to test proved economical for all thicknesses.

2. There is for any thickness of metal cut a limiting velocity of exit of the cutting jet at which complete utilization of the oxygen takes place, and there is a limiting value for the amount of oxygen required to produce a cut.

3. An increase in acetylene consumption, in oxygen consumption, or in the velocity of exit of the cutting jet beyond the limiting value does not produce increased efficiency in commensurate ratio.

4. A large majority of the blowpipes tested were equipped with excessive preheating flames for the thickness of metal the tip is specified for, and such excessive sized flames are disadvantageous both from the standpoint of economy of operation and quality of work performed.

5. Considerable improvement in economy of operation seems possible in cutting material of 2 in. thickness; possibly this condition may be found to exist for metal of other thicknesses than those used in the tests.

6. The maximum thickness of metal that may be economically cut with an oxyacetylene blowpipe of standard design when neither the material nor the oxygen is preheated and the cutting is done only from one direction is about 12 in.

7. Cutting blowpipes, due to their incorrect design, are subject to the same flashback troubles found in the welding blowpipes.

For the Welding Blowpipes.

1. The blowpipes most subject to the so-called phenomena of " flashback " are those in which the oxygen is delivered at a pressure in excess of that at which the acetylene is delivered.

2. All the blowpipes tested, including those in which the acetylene is delivered at an excess pressure as well as the so-called equal or balanced pressure blowpipes are subject to flashback phenomena on account of inherent defects in their design.

3. The cause of the development of the conditions producing flashback is the setting up, within the blowpipe tip and head, of a back pressure which retards or chokes off the flow of one of the gases.

4. This back pressure is the result of confining or restricting the volume flow of the issuing gases at the tip end.

5. Any cause tending to restrict the flow of the gases sets up a back pressure which immediately causes a change in the amount of each gas delivered to the mixing chamber.

6. A fluctuating gas-volume ratio, due to restriction of volume flow from whatever cause, prevents a blowpipe from maintaining constantly and at all times during operation the desired " neutral flame."

7. A blowpipe that can not maintain under all operating conditions a neutral flame can not logically be expected to produce sound welds.

8. All the blowpipes tested during this investigation either through improper gas pressures or improper interior design, or both, are incapable of maintaining a neutral flame (constant volume gas ratio) under all conditions of restricted gas flow and are therefore incapable of producing sound welds where there is any liability of the gaseous products of combustion being momentarily confined, such as occurs in practically all welding operations.

9. The ability of a blowpipe to consume an equal volume ratio of gases when burning freely and undisturbed in air is no criterion that it is capable of producing sound welds, that is, that it is not subject to detrimental fluctuations in gas ratio during a welding operation and therefore is capable of maintaining a neutral flame under all operating conditions.

. 10. Whether a blowpipe of present design will consume equal volume ratio of gases when burning freely and undisturbed in air depends on how nearly correct the operator sets the so-called "neutral flame," and experience indicates that the average operator checks the acetylene gas flow too much and actually develops an oxidizing rather than a neutral flame.

11. The question of the possible limiting strength and ductility or the efficiency of welds made by the oxyacetylene welding blowpipe must await the development of a more satisfactory instrument, and, having such an instrument, there is reason to believe that a weld of clean, sound metal can be made with assurance during any welding operation and that such welds will or can be made to possess the proper physical properties.

THE RADIO DIRECTION FINDER AND ITS APPLICATION TO NAVIGATION.[2]

By Frederick A. Kolster and Francis W. Dunmore.

[ABSTRACT.]

THE radio direction finder is a device for determining in a simple manner the direction of a radio transmitting station with reference to the point at which the direction finder is located. The direction finder has a number of very practical applications, of which one of the most important is its use as an aid to navigation.

Sound and visual signaling devices have been employed for many years as aids to navigation. Lighthouses and lightships with their characteristic light flashes and sound signals are established and maintained along the coasts and at harbor entrances in order that shipping may be carried on with maximum safety. During fog or thick weather, however, the sound and visual signaling devices do not give reliable service.

The radio direction finder is not affected by fog, and has the further advantage that it will operate over much greater distances than sound and visual signaling devices.

A common type of direction finder, as developed by the Bureau of Standards for installation on shipboard, and as at present used, consists of a coil of ten turns of copper wire wound on a frame four feet square which is mounted so that it may be rotated about a vertical axis. Associated with the coil is suitable radio receiving apparatus and also a device for reading the radio bearing.

As the coil is revolved, the intensity of this signal which is being received from the station whose location is to be determined, diminishes until a minimum is reached, which occurs when the plane of the coil comes to a position at right angles to the line of direction to the radio transmitting station. At this point of minimum signal, the radio bearing is read on a suitable scale, which may be either a fixed scale, or the card of a magnetic compass. A radio transmitting station intended primarily for direction finding work is often called a "radio beacon."

This paper deals briefly with the principles of the operation of the direction finder, but is primarily concerned with practical development which has made possible a device sufficiently simple

---

[2] Scientific Papers, No. 428.

and accurate for use as an aid to navigation, and with practical applications which have been made.

The developments have included a study of the distortion effects which may result from the presence of adjacent objects, such as the mass of a ship, and methods of eliminating errors which such distortions may cause in observed radio bearings. A particularly careful study has been made of distortion effects on shipboard and methods for correcting these effects by calibration.

Practical methods have been developed for simplifying the operation of the direction finder. The direction finder is essentially a nautical instrument and should be installed on shipboard where it may be used directly by the navigator in taking bearings on radio signal stations established on shore or on light vessels. This can be done with the simplified form. Bearings may thus be taken rapidly, at any time, and as often as desired.

The system here described should be carefully distinguished from another system of determining position by radio which is now in use, in which the ship transmits signals to radio compass stations on shore, which report to the ship its position, by radio. Delays and errors are inherent in the system with the radio compass on shore, and even under the most favorable conditions the time consumed in making a request for bearings, taking bearings, and getting the information in the navigator's hands, is too great.

The radio direction finder as described involves a number of unique features. It is designed to be installed over the ship's binnacle carrying the magnetic compass, and an additional scale is attached to the top of the binnacle and marked with the corrections obtained by calibrating the radio direction finder. By these means the radio bearings are obtained in a simple and direct manner. The electrical features have been made such that the only operations necessary when taking a radio bearing are one adjustment in the radio receiving set and the rotating of the direction finder coil.

The paper contains numerous photographs of a radio direction finder of the above-mentioned type, as installed in the pilot house of a lighthouse tender. Actual courses are shown which were run by means of radio bearings taken by the ship's navigator. The bearings were taken on the three radio beacons which have been established by the Bureau of Lighthouses at the approaches to New York harbor on Ambrose and Fire Island Lightvessels, and at Sea

Girt Lighthouse, Sea Girt, New Jersey. These automatic radio beacons are described and illustrated in the paper.

In these tests, positions were determined by cross bearings on the three radio beacons, and courses were set for one of the light vessel beacons by taking a radio bearing directly on the beacon.

The work described in this paper was done in close coöperation with the Bureau of Lighthouses, particularly the Lighthouse Depot at Tompkinsville, New York.

The system of radio direction finding described has already proved to be a very practical and an extremely effective aid to navigation, particularly in time of fog or thick weather.

The paper points out the importance of establishing as soon as possible radio beacons at the other important light stations on the Atlantic and Pacific coasts and the installation of radio compass equipment on shipboard.

SOME EFFECTS OF THE DISTRIBUTED CAPACITY BETWEEN INDUCTANCE COILS AND THE GROUND.[3]

By Gregory Breit.

[ABSTRACT.]

IT is well known that the effective capacity of two condensers connected in series is $\frac{C_1 C_2}{C_1+C_2}$ if C_1, C_2 are the capacities of the two condensers.

This fact would make it plausible to think that if two condensers of capacities of C_1, C_2 are connected in series with an inductance and if one or the other is adjusted until resonance of the system with an emf of given frequency is obtained, then the quantity $\frac{C_1 C_2}{C_1+C_2}$ must stay constant for different adjustments of C_1 and C_2.

In practice, however, accurate condensers are provided with shields and for this reason they must be used with the shielded terminals grounded.

If the shielded terminals of the two condensers are connected together and are grounded while the unshielded terminals are connected to the coil, it is found that the simple relation suggested above does not hold.

---

[3] Scientific Papers, No. 427.

It is shown that for resonance the values of C_1 and C_2 must satisfy a relation of the form

$$\frac{A}{C_1} + \frac{B}{C_2} + \frac{D}{C_1 C_2} + F = 0$$

so that if the two coil terminals are symmetrical

$$A + \frac{D}{C_1 + C_2} + F \frac{C_1 C_2}{C_1 + C_2} = 0$$

is the relation for resonance at a given frequency. This is a linear relation between $\frac{C_1 C_2}{C_1 + C_2}$ and $\frac{1}{C_1 + C_2}$ and experimentally it is found that such a relation holds.

THERMAL EXPANSION OF NICKEL, MONEL METAL, STELLITE, STAINLESS STEEL, AND ALUMINUM.[4]

By Wilmer H. Souder and Peter Hidnert.

[ABSTRACT.]

The increasing use of commercial nickel in spark plugs, of monel metal for high pressure steam valves, stems, seats, etc., of stellite for surgical and household uses, of stainless steel for numerous purposes such as aeroplane and automobile engine valves, pump rods and marine fittings and of aluminum, or its alloys, almost universally where lightness is necessary, has created a demand for data on the thermal expansion of these materials.

This paper includes original data on the thermal expansion of ten samples of commercial nickel, ten samples of monel metal, five samples of stellite, two samples of stainless steel and two samples of exceptionally pure aluminum, in addition to the results obtained by previous observers on the expansion of nickel and aluminum. All these materials except stainless steel were examined from room temperature to about 600° C. The samples of stainless steel were heated from room temperature to 900° C. The apparatus used was essentially the same as that described in Scientific Paper of the Bureau of Standards No. 352

Commercial Nickel (10 samples, 94 to 99 per cent. Ni.).—Five samples were hot rolled, and the remaining five samples of corresponding compositions were hot rolled and annealed. In most of the expansion curves of these samples of commercial nickel, a

---

[4] Scientific Papers, No. 426.

slight irregularity was perceptible in the region near 350° C., but there was no marked change or anomalous expansion such as was observed by the previous investigators in the case of pure nickel. Annealing of the hot rolled samples of nickel, usually caused a slight increase in the values of the coefficients of expansion.

Monel Metal (10 samples, 60 to 69 per cent. Ni.).—Two samples were cast, and three were hot rolled. The remaining five specimens of corresponding compositions and treatments, received additional heat treatment, that is, they were annealed. The expansion curves of monel metal were found to be fairly regular. The average coefficients of expansion of the various samples for the range from 25° to 300° C. are all practically equal. For the temperature range from 25° to 600° C. the average coefficients of the cast samples are greater than those of the hot-rolled alloys.

Stellite (5 samples of various grades).—The expansion curves show irregularities in the region between 300° and 500° C. The stellite containing 10 per cent. tungsten has the smallest coefficients of expansion of all the samples investigated. The hammered stellite has smaller coefficients than the unhammered sample of corresponding composition, which indicates that hammering may lower the value of the coefficients of expansion.

Stainless Steel (2 samples).—The expansion curves including the critical regions of an annealed and a hardened sample of stainless steel were determined. On heating, both samples indicated critical regions which extended from approximately 825° to approximately 855° C. The transformation point on cooling occurred at approximately 800° C. Up to the transformation regions, the heating and cooling curves of the annealed samples are fairly regular. In the case of the hardened stainless steel, the curve is irregular between 200° and 400° C., where the strains produced in hardening were released. Above 400°, this sample behaved like the annealed specimen. The coefficients of expansion of these stainless steels are less than the coefficients of ordinary iron or steel.

Aluminum (2 samples, 99.74 per cent.).—The thermal expansion of the two samples of cast aluminum investigated between room temperature and 600° C. may be represented by the following empirical equation:

$$L_t = L_0 \left[1 + (21.90t + 0.0120t^2) \ 10^{-6} \right]$$

CHARACTERISTIC SOFT X-RAYS FROM ARCS IN GASES AND VAPORS.[5]

By F. L. Mohler and Paul D. Foote.

[ABSTRACT.]

If an electron current is maintained by a potential V between a hot cathode and anode in a vapor at low pressure, then as V is increased successive changes occur in the spectrum excited by electron impact. The highest frequency v of each additional group of lines is related to the least potential required to excite the group by the quantum equation $Ve = hv$ or V (in volts) $= \dfrac{12345}{\lambda \text{ (in } A)}$.

The authors have studied the stages in the discharge by measuring the photo-electric effect of the radiation on two other electrodes entirely shielded from ions produced in the arc. This photo-electric current plotted as a function of the exciting voltage shows nearly a linear relation with changes of slope at critical potentials. In this manner potentials have been found which are determined by the limiting frequency of the softest X-ray series of a number of elements.

The table gives the observed potentials, and the corresponding wave-lengths for these X-rays. Carbon was studied in the compounds CO, CO_2, C_2H_4, and CCl_4. The latter compound also gave the chlorine points. The nitrogen point was obtained from air and the other points from the various elements at temperatures giving suitable vapor pressures.

The limits La of the L series for light elements, computed from X-ray spectral data by the relation $La = Ka - Ka$, are included in Table I. A plot of $\sqrt{1/\lambda}$ against atomic number shows that both the observed (column a) and computed points from magnesium to chlorine fall on the same straight line within the probable observational error. The points " b " for these elements lie on a nearly parallel line. They indicate a new X-ray series of feeble intensity. The value of La for sodium falls above the extrapolated straight line but is consistent with Millikan's recent observation of the La lines as $\lambda = 372$, and 376 A. The K limits found for carbon, nitrogen and oxygen fall close to the extrapolated

---

Ka line. Theories of atomic structure indicate that the potassium points must be ascribed to M series excitation.

Experiments with radiation from solids indicate the existence of soft characteristic X-radiation with no measurable general radiation under the best vacuum conditions. Nickel shows radiation starting at 80 volts. Experimental difficulties make the results obtained from solids less convincing than those from gases.

TABLE I.

Soft X-rays from Low Voltage Arcs.

Element	Observed Potentials in volts		λ in A		Computed λ La	Remarks
	a	b	a	b		
Sodium........	35.	17.	353.	726.	....	....
Magnesium....	46.	33.	268.	374.	263.	....
Phosphorus....	126.	95.	98.0	130.	92.2	....
Sulphur	152.	122.	81.2	101.	77.2	....
Ohlorine.......	198.	157.	62.3	78.6	61.9	....
Carbon........	272.	....	45.4	....	....	⎫
Nitrogen	374.	....	33.0	....	....	⎬ K series limits
Oxygen........	478.	....	25.8	....	....	⎭
Potassium	23.	19.	536.	650.	....	M series limits

THE MATHEMATICAL THEORY OF THE INDUCED VOLTAGE IN THE HIGH TENSION MAGNETO.[6]

By F. B. Silsbee.

[ABSTRACT.]

THE high tension magneto is an exceedingly complex electrical system, and any attempt to treat the phenomena on a mathematical basis necessarily involves numerous assumptions. The present paper considers only the short but very important period in the cycle of operations in the magneto between the moment of interruption of the primary current and the moment when the spark gap breaks down. During this period the magnetic energy stored in the primary inductance is in part transferred to electrostatic form and charges the primary and secondary capacities. Three different types of simplified electrical models are described, each of which serves to take account of certain of the characteristics of the complete device.

[6]Scientific Papers, No. 424.

The first of these, called the double coil model, consists of two separate circuits each containing resistance, inductance, and capacity. Such a model enables one to take account of the lack of perfect coupling between the primary and secondary circuits, and shows that the resultant secondary voltage wave contains a higher frequency ripple superposed on the principal wave. The amplitude of this ripple is relatively small if the circuits are closely coupled, as is the case of most magnetos.

The second type of model considered is called the single coil model and consists of a single resistance, inductance and capacity connected in series. Such a circuit would be equivalent to a magneto if the coupling between its windings was perfect, and gives a fairly good approximation to actual conditions in many cases. The circuit is sufficiently simple so that explicit expressions can be deduced for the maximum voltage attained under various conditions. Neither of these first two models allows for the energy losses in the iron except as their resistance may be arbitrarily increased to cover this point.

A better approximation in this regard is obtained by a third or closed coil model, which consists of a primary circuit of resistance, inductance, and capacity analogous to that of the single coil model together with a tertiary circuit having resistance and inductance which is coupled magnetically to the primary circuit. This tertiary circuit represents the eddy currents in the iron and equations can be obtained for the voltage wave form of such an aggregation of circuits.

The types of wave form corresponding to each of these three models are compared qualitatively with waves actually observed at the National Physical Laboratory. The crest voltage obtained at the Bureau of Standards by interrupting various primary currents, in certain actual magnetos, is also compared quantitatively with the values predicted for the circuits by the use of the single coil and closed coil models. While the agreement is not perfect, it is sufficiently close to indicate that the models may be useful in the design of such apparatus.

Methods are also given for the measurement of the various electrical constants entering into the several types of model here described.

RECOMMENDED SPECIFICATIONS FOR LIMESTONE, QUICKLIME AND HYDRATED LIME FOR USE IN THE MANUFACTURE OF GLASS.[7]

[ABSTRACT.]

The quality of lime to be used in the manufacture of glass depends upon the kind of glass to be made. Plate glass requires lime containing a high proportion of calcium and magnesium oxides, while cheaper glasses can make use of a less pure lime.

It is, therefore, recommended that limes be divided into three classes, containing 96, 91, and 83 per cent. of oxides of calcium and magnesium. It is also necessary that the calcium oxide content shall not vary from day to day. The maximum variation permitted is 2 per cent. All of these figures apply equally to limestone, quicklime and hydrated lime, the percentage being calculated upon the non-volatile matter of the material. Whichever material is used, it should be fine enough so that it will all pass a No. 16 sieve.

Ancient Forests in North Dakota. (*U. S. Geological Survey Press Bulletin, No. 480.*)—Fossils have been aptly called the illustrations in the great book recording the world's history, the pages of which are the layers of rock that form the outer part of the crust of the earth. By looking at some of the photographic reproductions of fossil plants we can restore in imagination the ancient vegetation of parts of the world.

Fossil plants are very abundant in the Fort Union formation, a series of Tertiary rock beds in North Dakota, where they are found in the sandstone, in the harder concretions or lenses, and in the clay between the beds of sandstone. Most of them, especially those in the clay, are preserved with remarkable fidelity. About 300 species of plants from this formation have been described, and the total number of species it contains may perhaps reach 500 or more, according to the Geological Survey.

This abundant fossil flora shows that what is now an almost treeless plain was once covered with splendid forests of hardwoods, interspersed with scattered conifers and ginkgos. The presence of numerous and at many places thick beds of lignite make it clear that in this region there were great swamps, which must have existed with but little change for long periods of time. Among the plants of this epoch were fig trees and a fan palm with leaves 5 or 6 feet across, indicating that the climate was as warm or warmer than that now prevailing on the South Atlantic slope of the United States.

---

[7] Circular No. 118.

Carbon Black. (*U. S. Geological Survey Press Bulletin, No. 480.*)—The demand for carbon black, which is produced from natural gas, has greatly increased during recent years, but the supply of natural gas is rapidly decreasing, a fact that is viewed with no little alarm by the producers and consumers and that has brought about a general demand for information on the subject. Accordingly, in 1919 the Geological Survey began a canvass of the situation, and the result of this canvass is a report entitled " Carbon Black from Natural Gas in 1920," by E. G. Sievers.

Carbon black is a fluffy, velvety black pigment, frequently confused with lampblack, which is gray in color and which is produced from oil or other carbonaceous material. For many of its uses carbon black is superior to lampblack in quality, but for some uses, as for certain pigments in paints, lampblack is superior.

Carbon black has been used as a pigment in printer's ink instead of lampblack since 1864. It is also used as a coloring and reinforcing material in the rubber industry and is extensively used in the paint trade.

About 10 per cent. of the carbon black produced annually is used in the manufacture of stove and shoe polish, phonograph records, black leather, bookbinders' board, buttons, carbon and other black and gray papers, typewriter ribbons, carriage cloth, celluloid, electric insulators, cement colors, crayons, drawing and marking inks, artificial stone, black tile, and tarpaulins.

The exports now amount to 15 per cent. of the output, but before the war they amounted to 33 per cent. They will probably never again reach this amount, owing to the increased demand in the United States for carbon black.

Preparation of Carbonate-free Sodium Hydroxide.—JACOB CORNOG, of Ohio State University (*Jour. Am. Chem. Soc.,* 1921, xliii, 2573-2574), has devised the following technic for the preparation of a solution of sodium hydroxide free from carbonates. Distilled water is boiled in an Erlenmeyer flask to remove dissolved carbon dioxide, then is cooled and covered with a layer of ethyl ether from 3 to 4 centimeters in depth. Pieces of metallic sodium, not exceeding 1 centimeter in diameter, are dropped into the flask, and remain suspended in the ether. The water present in the ether slowly converts the sodium into sodium hydroxide which passes into the aqueous layer. When the proper amount of sodium has been dissolved, the greater portion of the ether is removed by means of a pipette, the remainder by boiling the solution. The resulting aqueous solution of sodium hydroxide does not yield a precipitate with an aqueous solution of barium hydroxide; hence is free from carbonates. Fire and explosions never occur during the preparation, provided the layer of ether be kept sufficiently deep, so that the suspended sodium cannot come into contact with both the air and the water at the same time. J. S. H.

NOTES FROM NELA RESEARCH LABORATORIES.*

INTERLABORATORY PHOTOMETRIC COMPARISONS OF GAS-FILLED TUNGSTEN LAMPS.

By W. E. Forsythe and F. E. Cady.

At various times reports have been given of comparative tests made in a number of laboratories to show existing agreement in the photometry of incandescent lamps. Data of this character have been available for both the carbon and vacuum tungsten types, and it was felt that similar information on gas-filled lamps would be of value. The variety in types and efficiencies and the general use of the Ulbricht sphere for this class of lamps gives added interest to such a comparison.

The following seven laboratories participated: The Research Section and the Testing Section of the Engineering Department of the National Lamp Works, designated by R.N.L.W. and T.N.L.W.; the Photometric Laboratory of the Westinghouse Lamp Company (W.L.); the Electrical Testing Laboratories (E.T.L.); the Edison Lamp Works of the General Electric Company (E.L.W.); the Bureau of Standards (B.S.); and the Pure Science Department of the Nela Research Laboratories (N.R.L.).

The lamps tested consisted of three each of the regular commercial 100-watt, 500-watt and 1000-watt, the 1000-watt stereopticon type and the 900-watt lamp for moving picture projection. All were given a preliminary seasoning. They were first photometered at Nela Research Laboratories, then sent to the engineering Sections of the National Lamp Works and re-photometered at N.R.L. before being sent to the other laboratories. They were returned to N.R.L. and measured before being sent to the Bureau of Standards.

The results of the candlepower measurements are given in the table. Readings of current and voltage of the various laboratories checked so closely that the results are not included.

TABLE I.

Values Obtained by Various Laboratories of Mean Spherical Candlepowers Reduced to Lumens.

	VOLTS	N. R. L.	R.N.L.W.	T.N.L.W.	N. R. L.	W. L.	E. T. L.	E. L. W.	N.R.L.	B. S.
		L	L	L	L	L	L	F	L	L
100-watt										
1	112.5	1280	1280	1295	1310	1315	1280	1320	1275	1282
2	115.4	1250	1230	1257	1275	1295	1250	1280	1240	1240
3	116.1	1310	1275	1295	1315	1320	1300	1330	1290	1287
500-watt										
1	116.6	9000	8950	9140	9050	9250	8870	8900	9050	9076
2	117.3	8950	8950	9120	9100	9250	9000	9000	9050	9064
3	114.6	8200	8200	8320	8350	8550	8860	8950	8300	8322
1000-watt										
1	117.1	18750	18850	19150	18900	19350	18760	19300	19000	18980
2	117.9	18850	19000	19160	19050	19550	19000	19500	19200	19110
3	114.5	18350								
Stereopticon										
1	115.9	21750	22150	22600	21600	22100	22100	22150	21850	22630
2	116.95	27000	27200	28030	27000	27150	27000	27950	27450	28030
3	117.55	21350	21800	22630	21600	21900	21800	22450		
Movie										
1	30 A	25900	26250	26850	25400	25650	25800	25650	26350	26530
2	30 A	23900	24550	24870	23850	23900	24000	23400	23950	23890
3	30 A	25500	25950	26320	25250	25150	25800	25750	26000	26300

In view of the relatively large differences in color between the " movie " lamps and the others and the marked differences in the filament shapes and supports the agreement in the candlepower values is somewhat surprising and very satisfactory, particularly as the tests were made according to regular commercial practices. The color differene between the 500-watt gas-filled and a 1.25 w. p. c. vacuum tungsten is about the same as that between the 1.25 w.p.c tungsten and a 4 w.p.c. carbon lamp, and there is about the same color difference between the 500-watt and the " movie " lamp.

The complete paper will be found in the *Transactions of the Illuminating Engineering Society.*

NELA RESEARCH LABORATORIES,
    CLEVELAND, OHIO,
        January 25, 1922.

PERSULFATE REDUCTION.[1]
By S. E. Sheppard.

MESSRS. Lumière and Seyewetz have contested (*Rev. franc. phot.*, 1921, p. 42) the acceleration of persulfate reduction by iron salts reported by the author, as also the acceleration by silver salts. The effect of these has now been determined quantitatively over a considerable range of concentrations of acid and other conductors. The persulfate used in the experiments was purified by three recrystallizations; iodimetric titration showed 99.95 per cent. S_2O_8, and ammonia titration 100 per cent. The emulsion used was chiefly Seed 23, the plates being exposed in a sensitometer, developed with para-aminophenol, fixed twice in 20 per cent. hypo with 10 per cent. neutral sulfite; they were washed in ten changes of distilled water. Each plate was treated with the same volume of fresh reducer; the plates were kept rocking in a tray at 20° C. Densities were measured before and after reduction with a Martens' photometer.

In the majority of cases the reduction was proportional of a sufficient region of the characteristic curve for the per cent. change of γ, the development factor, to be taken as the measure of reduction. Every precaution was taken to prevent contamination by traces of chloride. Under these conditions quantitative evidence for acceleration by small quantities of iron and silver salts obtained. The effect of iron salts at very low initial acidity of the reducer was not very marked, but increased rapidly as the acidity increased, then again diminished and became negligible at an acidity of about .5 per cent. H_2SO_4. A quite similar effect of iron salts was found for the solution of pure precipitated metallic silver by persulfates.

The catalytic rôle of ferric and argentic ions appears to be explicable as follows: The writer has found that the high poten-

---

tials of persulfate solutions correspond to an unstable oxygen electrode, according to the irreversible reaction,

$$S_2O_8'' + H_2O = 2HSO_4'' + O.$$
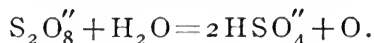
In agreement with the results of Lorenz (1906) and of Schoch (1910) on oxygen electrodes in presence of oxidizable metals, the writer considers that the first step in the dissolution of silver by persulfate consists in the formation of solid silver oxide, with possible intervention of silver peroxide. Little soluble in water, the reaction is accelerated by solvents for the oxide films, such as acids and ammonia.

The catalytic effect of silver ions may consist in part in catalysis of the reaction $S_2O_8'' + H_2O = 2HSO_4' + O$, but equally, or more, by the increase of acidity in persulfate solutions in presence of silver salts. In conjunction with A. Ballard, the author found that silver salts greatly accelerate the decomposition of persulfates in solution. The velocity is approximately proportional to the concentration of the silver ion, and, as followed by increased acidity, is nearly twice as great for ammonium as for potassium persulfate. It is pointed out that this increase in acidity is probably sufficient to account for the action of silver and ferric ions, which operate indirectly as promoters of acidity. This explains at the same time their relatively diminished effect as the acidity is independently increased.

It is pointed out that these results may contribute also to the explanation of the differential reduction with persulfates, inasmuch as local differences in effective hydrogen ion concentration may occur in a gelatin layer, according to the proportion of silver to gelatin. This would be in consequence of "buffering" action by the gelatin. The author criticizes Lumière and Seyewetz's theory of differential reduction, which is incompatable with the fact that plates exposed from the back give the same result as those exposed normally. In this connection he points out that different types of emulsions give different results in persulfate reduction. The investigation of this, and of the causes of differential reduction with persulfate is left for a later paper.

NOTES FROM THE U. S. BUREAU OF CHEMISTRY.*

A REPORT ON THE ZAMIA STARCH SITUATION.[1]

By J. F. Clevenger.

[ABSTRACT.]

Zamia floridana DC., growing in the vicinity of Miami, Florida, has an enlarged tuberous-like stem below the level of the ground, which enables the plant to withstand the fires that occur frequently in that region. Analysis of the rhizomes showed that it contained over 37 per cent. of starch. Attempts to cultivate the plant on a commercial scale have so far been unsuccessful, possibly due to the absence in the soil of the organisms forming the root tubercles. The starch prepared from the rhizomes is used by the natives as a food in limited amounts in making crackers, biscuits, and other food products requiring starch. The manufacturer depends for his supply chiefly upon collections by the local residents. Zamia starch has been marketed under the designation "Florida arrowroot." True arrowroot starch is obtained from Maranta root. This double use of the term arrowroot has led to confusion in the trade; hence the name " Florida arrowroot starch " or " Florida arrowroot flour " should not be used. The designation "flour" is distinctly objectionable, since during the process of manufacture tissue elements are practically eliminated. It is believed that the name "Zamia starch" should be applied only to the product obtained from Zamia plants.

DISTRIBUTION OF CERTAIN DRUGS BETWEEN IMMISCIBLE SOLVENTS.[2]

By W. O. Emery and C. D. Wright.

[ABSTRACT.]

STUDIES have been made of the effect of temperature and concentration on the distribution of caffeine between water and chloroform. The effect of the presence of other solutes in the

---

aqueous layer on distribution has been determined at 25°. The solubility of caffeine in water and certain aqueous solutions has been measured at 25°. Further proof of the existence of molecular compounds of caffeine with sodium salicylate and sodium benzoate in aqueous solution has been obtained by cryoscopic measurements. The distribution of antipyrine has been determined under similar conditions. The solubility of p-acetoxy-acetanilide in water and chloroform has been measured at 25°. Its distribution between water and chloroform has likewise been determined. Comparison of the distribution curves for caffeine and antipyrine between water and chloroform confirms the earlier assumption that the distribution ratios of these substances are nearly if not quite identical.

THE RELATIVE TOXICITY OF STRYCHNINE TO THE RAT.[3]

By E. W. Schwartze.

[ABSTRACT.]

The results of a series of experiments on the toxicity of strychnine to the rat are compared with the results which have heretofore been recognized for other animals or can be deduced for them from miscellaneous data in the literature. The comparative pharmacology of strychnine in mammals is outlined. The age (development) markedly influenced the toxicity of strychnine and the type of spasms produced. The rate of disposal of strychnine by the rat and its absorption from the stomach are discussed. The practical application of the observed phenomena is considered.

YEASTS AND OIDIA IN HIGH-GRADE EXPERIMENTAL BUTTER.[4]

By William R. North and George F. Reddish.

[ABSTRACT.]

Following a previous study by Redfield which fixed upon the numbers of yeasts and oidia in cream as indices of age and unfavorable conditions of storage and transportation, the authors examined a series of commercial, high-grade butter samples made in the Grove City Creamery. The examination consisted in micro-

[3] *U. S. Department of Agriculture Bulletin 1023*, issued January 9, 1922.

[4] Published in *J. Dairy Sci.*, **4** (1921) : 510.

scopic counts of the numbers of yeasts and oidia per cubic
centimeter of the mixed cream going into the churn. In contrast
to these figures microscopic counts were made from the whey
extruded from melted samples of the resulting butter. Very few
of the cream samples examined showed yeasts in excess of 5000
per cubic centimeter, and in no case did the figures exceed 75,000
per cubic centimeter. By the microscopic method used no oidia
were found since the number must exceed 5000 to be counted.
Cultures showed, however, yeasts and oidia to be present in small
numbers. Counts made from the butter showed the numbers of
yeasts and oidia to be consistently less than 5000 per cubic centi-
meter when freshly made. Careful experiments in shipping these
butters and storing them under refrigerator temperatures showed
that yeasts multiply readily in moderately salted butter whenever
the temperatures of transportation or storage permit, whereas
oidia were restrained from growing by the salt present. The count
of oidia, therefore, in such butter is attributable to the cream and
more or less indicative of the condition of that cream before
manufacture. The small numbers of yeasts and oidia found in
these high-grade creamery butter samples scoring 93 or over are
in sharp contrast to the numbers found by Redfield in a large series
of butter and cream samples in a centralizer creamery whose out-
put regularly scored 88 and 89.

Alaska Once Subtropical. (*U. S. Geological Survey Press
Bulletin, No. 481.*)—The ancient vegetation of the Arctic region,
as is shown by a study of its fossil plants, indicates that its climate
was once very unlike that which prevails there now. Instead of con-
sisting of a handful of small plants struggling for life amid snow
and ice in a scant, almost perpetually frozen soil, its vegetation was
abundant and luxuriant and included ferns and palm-like plants that
grow only in a mild and probably frostless climate. This vegetation
flourished in the Arctic region from at least late Paleozoic to middle
Cenozoic geologic time, millions of years ago, before man existed.
Although these lands are now so inhospitable and are rarely visited,
the Geological Survey has gathered a large amount of information
concerning their fossil floras.

A study of the coal beds of the Cape Lisburne region has inci-
dentally disclosed many fossil plants. These coal beds are extensive
and are the only known commercially valuable mineral resources of
that region. A little coal is occasionally mined for vessels that are
short of fuel, which, as there is no harbor, lie offshore and peril-
ously load on a few sacks of coal by means of lighters.

Cape Lisburne is the bold headland which marks the northwest end of a land mass that projects into the Arctic Ocean from the western coast of Alaska about 160 miles north of the Arctic Circle and about 300 miles directly north of Nome. Even Cape Lisburne is by no means the northern limit of the fossil plants of this nearly tropical vegetation, for they have been found in the rocks 180 miles northeast of Cape Lisburne.

Antirachitic Vitamine.—Results obtained in a study of experimental rickets in rats, made by E. V. McCollum, Nina Simmonds, P. G. Shipley and E. A. Park, of Johns Hopkins University (*Jour. Biol. Chem.*, 1922, 1, 5-30), support the view that cod liver oil contains an antirachitic vitamine as well as fat-soluble A. The fat-soluble A vitamine promotes growth and prevents the occurrence of xerophthalmia (an eye disease), while the antirachitic vitamine prevents the occurrence of rickets. McCollum and his associates find that "cod liver oil contains in abundance some substance which is present in butter fat in but very slight amounts, and which exerts a directive influence on the bone development and enables animals to develop with an inadequate supply of calcium much better than they could otherwise do."

J. S. H.

Precautions in the Use of Nessler Solution.—Nessler solution is an aqueous solution of potassium mercuric iodide rendered alkaline by addition of the hydroxide of a fixed alkali. It reacts with solutions of ammonium salts to yield a yellow solution containing dimercuric ammonium iodide. Extensive use is made of this reaction in analytic chemistry for the quantitative determination of ammonia colorimetrically. At times a cloud or precipitate may also form and interfere with the determination. According to Clarence E. May and Harry P. Ross, of Indiana University (*Jour. Am. Chem. Soc.*, 1921, xliii, 2574-2575), this phenomenon may be avoided by taking certain precautions. Only distilled water may be used for dilutions; tap water, which has been rendered ammonia-free, is unsatisfactory. Prior to use, the glass vessels, in which the reaction is carried out, should be washed with chemically pure nitric acid, then with water in order to remove the mercury film from a previous determination. Not over 1.0 milligram of ammoniacal nitrogen should be present in 150 c.c. of solution. The proper volume of Nessler solution should be added rapidly and at one time, never in several successive portions. An intimate mixing of the solutions occurs instantaneously without agitation. In fact, stirring and shaking must be avoided. Twenty minutes after addition of the reagent, water may be added gently to dilute to any desired volume.

J. S. H.

NOTES FROM THE U. S. BUREAU OF MINES.*

WATER GAS TAR EMULSIONS.
By W. W. Odell.

ALMOST every gas plant where carbureted water gas is made experiences some difficulty in separating the tar from the water condensing from the gas. The fact that this trouble is ever present in some plants, and seldom present in others, indicates that certain operating variables have considerable to do with the formation of separable tar-water emulsions. The U. S. Bureau of Mines, in coöperation with the University of Illinois Engineering Experiment Station, the Illinois State Geological Survey, and the Illinois Gas Association, has investigated the causes for emulsion difficulties in water gas plants.

It was found that the tar differs in composition and quality according to the part of the cooling system from which the sample is collected, and that usually the tar which condenses from the gas in the early stages of cooling forms the most stable emulsions. Among the factors that affect the quality of the tar are the temperature in the checker chamber, spacing and condititon of checker-brick; rate of input, distribution, and character of the carbureting oil used, quantity of excess steam used, character of condensing system and rate of cooling the gas. Fuller details are given in a report that will be published by the Bureau of Mines.

MILLING METHODS IN TRI-STATE ZINC DISTRICT.
By W. H. Coghill and C. O. Anderson.

THE Bureau of Mines, in coöperation with the Missouri School of Mines and Metallurgy, the Miami School of Mines, Oklahoma, and operators of the Tri-State zinc district, is investigating milling methods in that district with a view to improving recoveries and decreasing losses of mineral in the tailing. The chief problem confronting the operators is the loss of zinc in the chats (locked grains of blende and flint). Generally the locked blende is in sufficiently large grains to permit use of gravity separation,

---

* Communicated by the Director.

but much of the flint contains such minute specks of blende that gravity separation is out of the question, although the assay indicates a desirable grade of ore. The operators have made heroic efforts to recover the locked minerals, but in general, the mill systems developed have not been satisfactory, and are more or less complicated. The Bureau's metallurgists have succeeded in developing a new type of jig, which has given good results in the laboratory tests for control work in mill sampling and testing. Tests on a larger scale with this jig are now under way. Fuller details will be found in a recent paper issued by the Bureau in mimeograph form.

MOMENTARY HEATING OF INFLAMMABLE COAL DUSTS.

By Guy B. Taylor.

In investigations on the explosibility of coal dust, by the Bureau of Mines and others, one of the unsettled points is whether the coal-dust particles in an explosion unite directly with the oxygen of the air, or whether predistillation of gas from the coal-dust particle takes place and is a factor in propagating the explosion from particle to particle.

Experiments in the Bureau's laboratories, in dropping a hot metallic body through a dust cloud in an inert gas (nitrogen) seemed to show that predistillation, if any, was negligible, although when air was present an explosion would ensue. Experiments were also tried in which the coal dust was momentarily heated by passing it through an electrically heated porcelain tube, the dust being brought into suspension by a blast of hot inert gas (nitrogen) passed through the tube. These experiments also seemed to show no distillation. Results of a third series by a bomb method were inconclusive. It was not practicable to continue this line of work, but the results have been published in mimeograph form for the benefit of others who may be interested in carrying on further experimentation.

THE FRANKLIN INSTITUTE.

(Proceedings of the Stated Meeting held Wednesday, February 15, 1922.)

HALL OF THE FRANKLIN INSTITUTE,

PHILADELPHIA, February 15, 1922.

DR. WALTON CLARK, President of the Institute, *in the Chair.*

The Board of Managers submitted its report. The report recorded the election to membership of Messrs. Clifford Whitman Bates, Charles Douglas Galloway and William E. Saunders; lectures before Sections by L. W. Austin, Ph.D., Head, U. S. Naval Radio Research Laboratory, Bureau of Standards, Washington, District of Columbia, on "Recent Developments in Radio Communication"; by L. J. Henderson, M.D., Professor of Biological Chemistry, Harvard University, Cambridge, Massachusetts, on "Applications of Physical Chemistry to the Physiology of Breathing"; lecture before the Stated Meeting January 18, 1922, by Honorable William D. B. Ainey, LL.D., L.H.D., Chairman of the Public Service Commission of Pennsylvania on "The Highway System of the State of Pennsylvania"; and additions to the library by gift, 42 volumes and 156 pamphlets, by purchase 44 volumes.

L. J. Briggs, M.S., Ph.D., Chief of Engineering Physics Division, Bureau of Standards, Washington, District of Columbia, presented the paper of the evening on "The Resistance of the Air." Wind-tunnels for obtaining air-streams of known velocity were described as well as aerodynamical balances for measuring air forces on a model; reference was made to the air-resistance equation and dynamical similarity in air-resistance measurements. Consideration was given to the air-resistance of bodies of various forms and to air-foils. Reference was also made to the problem of the measurement of the resistance of projectiles. The subject was illustrated by lantern slides.

A unanimous vote of thanks was extended to Doctor Briggs.

Adjourned.

R. B. OWENS,

Secretary.

REPORT OF THE PRESIDENT FOR THE FISCAL YEAR ENDING SEPTEMBER 30, 1921.

TO THE MEMBERS OF THE FRANKLIN INSTITUTE:

This writing is the report which your Board of Managers has instructed me to make to you of the affairs of the Institute for the Institute year ending September 30, 1921.

The work of the Institute was carried on through the year successfully as the Management think, and as you may learn in detail from a reading of the reports of the several committees of the Board and of the Institute as they will appear in the 1922 Year Book. As is customary in the Managers' report, we quote briefly from the Committee reports, with such comment as seems useful.

The Committee on Exhibitions (Mr. Benjamin Franklin, Chairman) reports on the present status of the Sesqui-Centennial Exhibition as it affects The Franklin Institute. This report does not call for any specific comment here.

The Committee on Museum (Mr. Outerbridge, Chairman) reports the addition to the Museum of models and apparatus of great historic interest, among them the air pump of Dr. Joseph Priestley, presented by Mr. Coleman Sellers, Jr.; an odometer made and used by Isaiah Lukens, one of the early Vice-presidents of the Institute, presented by Mr. Henry R. Towne; a printing telegraph, the invention of George H. Phelps, presented by the Pennsylvania Hospital; and an Oertling balance, with weights, presented by Dr. Harry F. Keller.

Most of our models are now so crowded on the shelves of the Institute that they are practically not available to the student, the inventor and the mechanician. We have reason to believe that we will soon be able to store and properly display our many valuable models and pieces of apparatus of historic value in a building owned and operated by the Institute.

The report of the Committee on Sectional Arrangements (Dr. Keller, Chairman) tells in detail of the lectures—nineteen in number—delivered during the year before the various sections of the Institute. This report is interesting to read, but offers little opportunity for presentation in brief.

The Committee on Meetings (Dr. Alleman, Chairman) reports the lectures delivered before the Institute. Eight stated meetings were held during the year. This report, like that of the Committee on Sectional Arrangements, is interesting reading, dealing with one of our very important functions, but not susceptible of summarization.

The Committee on Publications (Mr. Rosengarten, Chairman) reports, among other interesting data, the publication of the book " Physics of the Air," Dr. W. J. Humphreys, of the United States Weather Bureau, author. Of this important publication 960 copies have been sold, and the demand is still strong. The book is a recognized authority and of great value to meteorologists and to navigators of the air. It is a volume also of great interest to the layman. The Committee on Publications also reports a slight, but encouraging, decrease in the cost of publication of the JOURNAL and of the Year Book.

The Committee on Library (Dr. Creighton, Chairman) reports additions to the library of 2901 volumes and pamphlets, an increase of 393 titles over the gain of the previous year. The great sugar library bequeathed to the Institute by Mr. Lewis S. Ware—about 25,000 volumes and pamphlets—is still in temporary storage in a fire-proof warehouse. As indicated elsewhere in this report, we have the expectation of soon being able to store this valuable collection of books in a fire-proof building owned by The Franklin Institute.

From the report of the Committee on Instruction (Mr. Paul, Chairman)— being for the ninety-seventh year of our School of Mechanic Arts—we learn that the classes fell off a little, but very little, in numbers from the unusually large enrollment of the previous year. Again we found it necessary to open the school five evenings a week instead of four—our practice prior to 1919—in order comfortably to accommodate the students. The number of students graduated at the class exercises in April—being sixty-nine—is greater than in any previous year in the history of the School.

The Committee on Science and the Arts (Mr. Masland, Chairman) reports twenty cases disposed of during the year and nineteen awards made. This is an unusually large record of disposition of cases and of awards. The report refers to the publication in the 1921 Year Book of a list of all the awards made on recommendation of the Committee since its establishment in 1834. The total is 892 awards made.

The Committee on Endowment (Mr. Sellers, Chairman) gives some important data relative to the Bartol Bequest, and the very interesting information of another bequest so far not reported to you. Mr. George Theodore Roberts, who died in March, 1921, made The Franklin Institute one of the residuary legatees of his large estate, his daughter having a life interest in the property. Mr. Sellers has been advised that the Institute's interest as one of the residuary legatees probably amounts to $40,000.

The Committee on Stock and Finance (Mr. Forstall, Chairman) reports a very sound financial condition, although for the immediate present our operating expense exceeds our operating revenue. This is a condition anticipated by your Board when we told you a year ago of the then increase in our balance of assets over liabilities, and that at the end of the year, for the first time in memory the Institute would be out of debt, except as between departments. Our work costs more than our regular income affords, but less than our regular income plus the occasional bequests applicable to operating expenses, as over a period of years. In the confidence that this will be a continuing condition we have gone on with our work, spending what was necessary to its efficient conduct. So we propose to go on with it as long as we have available funds, or bank credit or salable property—never to the extent of imperilling creditors' interests—or of using trust funds other than as designated by their donors—but otherwise to the limit of possibility. Such a course has had your approval in the past, as we hope it has your approval in the present.

The Committee on Election and Resignation of Members (Mr. Lesley, Chairman) reports a total membership of 1386, an increase of six members for the year. This increase—though small—is very welcome, being the first in several years. If the Institute depended for its financial support upon the membership dues received it would do little work indeed. Why we have less than six hundred resident members in this great industrial city is a question we have not been able to answer. None of our efforts to increase our membership has had more than slight success. Of course our location is against us. When dreams come true and we are on the Parkway, perhaps our membership will increase.

The Committee to carry into effect the intent and purposes of the Henry W. Bartol Bequest was duly appointed, as instructed by your resolution of November 17, 1920. The members of the Committee are:

Mr. Charles Day, Chairman;
Dr. Joseph S. Ames, of Johns Hopkins University;
Mr. Coleman Sellers, Jr;
Dr. Arthur L. Day, of the Carnegie Institution of Washington;
Mr. C. C. Tutwiler;

with the President and the Secretary of the Institute as ex officio members.

The Committee, with the concurrent approval of the Franklin Fund and Building Committee (Mr. Howson, Chairman), anticipates that this year we will be able to begin construction of a laboratory, to be owned by The Franklin Institute, and to be occupied in part by the research work to which the Estate of Henry W. Bartol is dedicated.

The principal of the Bartol Bequest available as of December 31, 1921, is approximately $1,300,000, and there is an accumulated interest fund as of that date of about $250,000. The settlements made effective with the contestants of the will will result ultimately in an addition to the fund of about $600,000. It will be some years before this fund of $600,000 will be available.

The Committee therefore finds the Bartol Bequest with an accumulated income of $250,000 and the expectation of a continuing income of from $75,000 to $80,000 per annum, to later increase to probably $100,000 per annum.

It is proposed, with the approval of the Franklin Fund and Building Committee and of the Board of Managers of the Institute, and as soon as the necessary legal and other procedures may be observed, to erect a laboratory on three of the twelve lots owned by the Institute on Nineteenth Street between Cherry and Race Streets. It is expected the laboratory will cost approximately $250,000, of which $100,000 will be provided from the accumulated income from the Bartol Research Fund, and $150,000 by the Institute through its Franklin Fund and Building Committee. This laboratory, which will be of a character to harmonize with the other buildings of The Franklin Institute group which we expect will ultimately occupy the other lots owned by the Institute at this location, will be sufficient to house the Bartol research work and all of the chemical and physical laboratory work of the Committee on Science and the Arts and of all other departments of The Franklin Institute.

The equipment, except for certain standard apparatus that is immediately indicated as necessary, is to be installed gradually as the necessities of the research work in hand indicate. The contribution of the Bartol Research Fund to the cost of the laboratory building is measured by what we estimate it would cost the Committee on the Bartol Bequest to erect a building suitable for its work at a less expensive site. The building being owned by The Franklin Institute, the Bartol Research Bequest will be given a right to use the laboratory in its work for a period that may be definitely fixed or may be unlimited, according as we shall decide later.

The management of the work of the Bartol Research Committee will be in the hands of Dr. R. B. Owens, Director, reporting to the Committee, and with such research professors and fellows as it may be found necessary or important to engage. A sub-committee of Dr. Owens, Chairman; Dr. Joseph S. Ames, and Dr. Arthur L. Day, has been appointed to engage the necessary staff.

The Institute is to be congratulated upon this prospect of soon starting work on a building that will house a portion of its activities, and as we confidently anticipate, will be but the first step toward the construction of a group of buildings, now to be discussed herein.

Your Board thinks it wise at this time, and in this connection, to advise you of its hopes and ambitions for the future housing and conduct of the work of the Institute.

The laboratory necessary to the proper housing of the Bartol research work, and of the chemical and physical work of the Committee on Science and the Arts, and of other departments of the Institute, has had reference herein. Our hope is that ultimately this laboratory will be one of a group of three buildings. We look forward to the date of the realization of our hopes and expectations, to see a building at the corner of Nineteenth Street and the Parkway, exteriorly worthy of a place among the noble structures then to be its neighbors and bearing a dignity worthy of the great name it will bear, and interiorily sufficient and suitable to the proper housing and conduct of all the Institute's work and equipment, except that the laboratory and museum are to be otherwise sheltered. The third building of the little group devoted to the promotion of the mechanic arts, when our hopes find fulfilment, will be a so-called " Scientific and Technical Museum." In it will be properly arranged and connected for illustration and for operation, the many important models and facsimilie apparatus now possessed by the Institute, and the multitude of such other things of interest to a follower of the mechanic arts as we have assurance will come to us when we are prepared properly to care for them. We believe that such a museum has no example in America. The American student, historian, mechanician or inventor, desiring to trace the development of an art through the study of concrete examples, must now journey to Europe to find what we will be able to present to him when our proposed museum is in operation.

Such a group of buildings so equipped will be without counterpart in America. The value of the opportunity therein offered to the student, the scientist and the mechanician cannot be exaggerated in statement. To provide and equip these buildings is upon the program your Board now presents to you—the membership of the Institute.

Does this appear an unduly ambitious program? We think it is not, and we ask you, members of the Institute, when considering it to remember that the Institute's wagon has ever been hitched to a star, and that, so drawn, it has come nearly to the hundredth year post on its road, maintaining still, as we believe, the virility and enthusiasm of youth and as capable as ever of vision and of accomplishment.

You will note that however ambitious our program may appear, it comprehends no departure from the scheme of usefulness laid out by our founders. With greater opportunity, more funds, and the example and experience of nearly a hundred years of service for our guidance, we of this generation may reasonably hope for ourselves and our successors to extend the benefits of the Institute's work to an ever widening circle—the interest being still confined to the Promotion of the Mechanic Arts—the vision being still that which inspired the founders and the generations of workers who have brought the Institute down the the century to our day and custody. We remember with pride what of public good these men accomplished—generally, if not always—with very limited financial resources—their one unlimited resource the spirit of devotion. May we not confidently expect our successors in membership to have this spirit of devotion in equal measure, and, with the experience and example of our predecessors to inspire and guide them, to produce results, as expressed in usefulness to the public, somewhat commensurate with the financial resources and equip-

ment we leave to them? We of your Board of Managers believe we may so confidently anticipate greater results to come with more nearly adequate funds and equipment, and so believing, we submit our program. In the absence of objection we shall regard it as having your approval. We do not doubt that the Institute will ultimately reach the goal this program sets for it. When—no one can say. It is probable that the first step—the laboratory building—will be begun this year, and that the research work of the Bartol Foundation will be fully under way in it at the celebration of our centennary in 1924.

We now own all the land useful in carrying out our full program, except for one lot, and without this lot we can carry out our program, with somewhat re-duced convenience of operation. Our funds dedicated to buildings will nearly be exhausted by the laboratory cost. So from the completion of our laboratory our building program must await the acquisition of more funds. The main building, equipped and occupied, will cost approximately one million dollars. The next step in our program is the erection and equipment of the scientific and technical museum, costing probably two hundred and fifty thousand dollars. The order of erection of these two buildings—the main building and the museum—might be reversed and the museum be the first to follow the laboratory.

Since we will have greater operating expenses in the new buildings, and since we cannot greatly increase our regular income, we think we should not venture on the next step of our program—the erection of the larger building—until we have a larger regular income dedicated to operating expenses. We think the Institute would not be justified in undertaking the full program now before us without an added endowment of a million dollars.

Thus the roughly estimated cost of completing our full program is two and a quarter million dollars. We believe that in the example of the founders of the Institute we may find the guide to the realization of our ambition. Effi-cient work in the public interest, the full utilization of what property has been confided to us, will in the future, as in the past, meet the approval of people seeking to dedicate some part of their accumulated wealth to the promotion of the mechanic arts. Always a part of our program is the efficient and economic application of our financial resources to such ends. We do not doubt that living to this part of our program in the future, as we have striven to live to it in the past, will bring such increase in financial resources as will make possible the full realization of the ambitions your Managers have herein discussed.

Respectfully submitted,

WALTON CLARK,
President.

PHILADELPHIA, January 18, 1922.

STANDING COMMITTEES, 1922.

OF THE BOARD.

ELECTIONS AND RESIGNATIONS.
Robert W. Lesley, Chairman.
Gellert Alleman.
Alfred W. Gibbs.
Clarence A. Hall.
Marshall S. Morgan.

EXECUTIVE.
E. H. Sanborn, Chairman.
Charles Day.
Walton Forstall.
Alfred W. Gibbs.
Alfred C. Harrison.

INSTRUCTION.
Lawrence T. Paul, Chairman.
George A. Hoadley.
Harry F. Keller.
Edward V. McCaffrey.
James S. Rogers.

SECTIONAL ARRANGEMENTS.
Harry F. Keller, Chairman.
Gellert Alleman.
Robert W. Lesley.
Haseltine Smith.
C. C. Tutwiler.

ENDOWMENT.
Coleman Sellers, Jr., Chairman.
G. H. Clamer.
Alfred C. Harrison.
Nathan Hayward.
Wm. Chattin Wetherill.

EXHIBITIONS.
Benjamin Franklin, Chairman.
Francis T. Chambers.
Theobald F. Clark.
Charles Day.
Charles A. Hexamer.

PUBLICATIONS.
George D. Rosengarten, Chairman.
G. H. Clamer.
W. C. L. Eglin.
George A. Hoadley.
E. H. Sanborn.

STOCKS AND FINANCE.
Walton Forstall, Chairman.
Benjamin Franklin.
Alfred C. Harrison.
James S. Rogers.
E. H. Sanborn.

OF THE INSTITUTE.

LIBRARY.
Charles E. Bonine.
G. H. Clamer.
H. J. M. Creighton.
W. H. Fulweiler.
Clarence A. Hall.
George A. Hoadley.
Harry F. Keller.
C. W. Masland.
Marshall S. Morgan.
George F. Stradling.

MEETINGS.
Gellert Alleman.
Joseph S. Ames.
G. H. Clamer.
Allerton S. Cushman.
Arthur L. Day.

MEETINGS (Continued).
W. H. Fulweiler.
Herbert E. Ives.
A. E. Kennelly.
Ralph Modjeski.
George D. Rosengarten.

MUSEUM.
Hugo Bilgram.
Arthur L. Church.
Charles Day.
W. C. L. Eglin.
George A. Hoadley.
C. W. Masland.
A. E. Outerbridge, Jr.
Charles Penrose.
H. H. Quimby.
Coleman Sellers, Jr.

COMMITTEE ON SCIENCE AND THE ARTS.

*(Abstract of Proceedings of the Stated Meeting held Wednesday,
February 1, 1922.)*

HALL OF THE FRANKLIN INSTITUTE,
PHILADELPHIA, February 1, 1922.

MR. CHARLES W. MASLAND, *in the Chair.*

Dr. James Barnes was unanimously elected Chairman for the year 1922.
The following reports were presented for final action:

No. 2775: Automatic Die Cutting Machine. The Edward Longstreth
Medal to Mr. Joseph Keller, of Brooklyn, New York.

No. 2777: Chlorinator. The Edward Longstreth Medal to Messrs.
Martin F. Tiernan and Charles F. Wallace.

R. B. OWENS,
Secretary.

SECTIONS.

Section of Physics and Chemistry.—A meeting of the Section was held in
the Hall of the Institute on Thursday evening, January 12, 1922, at eight o'clock,
with Mr. W. H. Fulweiler in the Chair. The minutes of the previous meeting
were read and approved.

Ralph H. McKee, Ph. D., Professor of Chemical Engineering in Columbia
University, New York City, delivered a lecture on " Gasoline from Oil Shale."
The possible American sources of motor fuel were considered. The American
deposits of oil shale, the destructive distillation of such shale, and the production
of gasoline from the crude distillate were described. The lecture was illustrated
with lantern slides and with specimens of typical oil shales and shale oils.

The communication was discussed by Doctors Porter and McKee, Messrs.
Fulweiler, Tutwiler, Lesley and others. On motion of Mr. Tutwiler, a vote of
thanks was extended to Doctor McKee. The meeting then adjourned.

JOSEPH S. HEPBURN,
Secretary.

Electrical Section.—A meeting of the Section was held in the Hall of the
Institute on Thursday evening, February 2, 1922. The meeting was called to
order by Prof. James Barnes. The minutes of the previous meeting were
approved as printed in the JOURNAL.

The paper of the evening on " Recent Developments in Radio Communi-
cation " was presented by L. W. Austin, Ph.D., D.Sc., Head, U. S. Naval Radio
Research Laboratory, Bureau of Standards, Washington, D. C. Attention was
given to the recent development in and the present status of long distance radio
communication; its methods, its problems and difficulties, its reliability and
limitations; with the laws of transmission and their experimental verification.
Facts were presented regarding the principal high power stations of the world
now in operation or under construction. Announcement was made of plans for

long distance communication, and with long distance radio in the future. The subject was illustrated by lantern slides.

After a brief discussion a unanimous vote of thanks was extended to the speaker.

Adjourned.

ALFRED RIGLING,
Acting Secretary.

MEMBERSHIP NOTES.

ELECTIONS TO MEMBERSHIP.

(Stated Meeting, Board of Managers, February 8, 1922.)

HONORARY MEMBERSHIP.

DR. RALPH MODJESKI, New York City and Philadelphia.
ADMIRAL WILLIAM S. SIMS, U. S. N.
SIR JOSEPH JOHN THOMSON, Trinity College, Cambridge, England.

RESIDENT.

MR. CLIFFORD W. BATES, 403 N. Narberth Avenue, Narberth, Pennsylvania.
MR. CHAS. DOUGLAS GALLOWAY, 8409 Anderson Street, Chestnut Hill. Philadelphia, Pennsylvania.
MR. WM. E. SAUNDERS, U. G. I. Company, Broad and Arch Streets, Philadelphia, Pennsylvania.

CHANGES OF ADDRESS.

DR. GEBHARDT BUMCKE, Trades Oil Products, Inc., 172–180 Frelinghuysen Avenue, Newark, New Jersey.
MR. WM. J. BURGESS, Pennsylvania Coal Products Company, Petrolia, Pennsylvania.
MR. GEO. E. KINNIER, 37 W. Church Street, Bethlehem, Pennsylvania.
MR. FRANKLIN P. McCONNELL, care of Day and Zimmermann, Inc., 611 Chestnut Street, Philadelphia, Pennsylvania.
MR. J. MILLIKEN, President, Pittsburgh Testing Laboratory, P. O. Box 1115, Pittsburgh, Pennsylvania.
MR. C. E. SARGENT, 909 Twentieth Street, Rock Island, Illinois.
DR. LESLIE DENIS SMITH, 2472 Ontario Road, N. W., Washington, D. C.

NECROLOGY.

Dr. Charles Baskerville, College of City of New York, New York City, New York.

Mr. Frank H. Clement, Land Title Building, Philadelphia, Pennsylvania.

Mr. John C. Pennie, 165 Broadway, New York City, New York.

LIBRARY NOTES.

PURCHASES.

American Institute of Chemical Engineers.—Transactions, 1920. 1921.

CURIE, MARIE SKLODOWSKA (Mme. Pierre).—La Radiologie et la Guerre. 1921.

FAJANS, K.—Radioaktivität und die neueste Entwickelung der Lehre von den chemischen Elementen. 1921.

FREUND, IDA.—Experimental Basis of Chemistry. 1920.

FRIEND, J. NEWTON.—Text-book of Inorganic Chemistry. Iron and its Compounds. 1921.

HOLLEMAN, A. F.—Text-book of Inorganic Chemistry. 1921.

HOLLEMAN, A. F.—Text-book of Organic Chemistry. 1920.

KÖGEL, P. R.—Die Palimpsestphotographie. 1920.

Scientific Papers of the Hon. Henry Cavendish, 2 vol. 1921.

SILBERSTEIN, L.—Elements of Vector Algebra. 1919.

Society of Chemical Industry.—Reports on the Progress of Applied Chemistry. 1917–20.

GIFTS.

Allis-Chalmers Manufacturing Company, Steam Turbine and Alternator Units and Power Transformers. Milwaukee, Wisconsin, 1921. (From the Company.)

American Annual of Photography for 1922. New York City, New York, 1921. (From Mr. Frank V. Chambers.)

American Steel and Wire Company, Booklet of Stucco Houses. Chicago, Illinois, 1921. (From the Company.)

Baker Brothers, Booklet 121 of Boring and Drilling Machines and Keyseaters and Slotters. Toledo, Ohio, no date. (From the Company.)

Biddle, James G., Catalogue 940, " Megger " Testing Sets. Philadelphia, Pennsylvania, no date. (From Mr. Biddle.)

Bristol Company, Preliminary Catalogue No. 1501. Waterbury, Connecticut, 1921. (From the Company.)

Canadian Department of the Interior, Water Resources Papers Nos. 28, 29 and 30. Ottawa, Canada, 1921. (From the Department.)

Canada Department of Mines, Production of Coal and Coke in Canada and Production of Copper, Gold, Lead, Nickel, Silver, Zinc, and Other Metals in Canada. Ottawa, Canada, 1921. (From the Department.)

Canadian Minister of Public Works, Rep   for 1921. Ottawa, Canada, 1921. (From the Canadian Minister.)

Centrifugal Fan Company, Pamphlet of V   Part in a Better World. Newark, New Jersey, no date. (From t

Clark Tool Works, Incorporated, The Clark   tal Cutting Band Saw. Belmont, New York, 1921. (From the

Coffin Valve Company, Coffin Balanced Needle Valv   ponset, Boston, Massachusetts, no date. (From the Company.)

Colgate University, Annual Catalogue 1921–1922. Hamilton   ew York, 1921. (From the University.)

College of Physcians, Transactions, vol. 42. Philadelphia, Pennsylvania, 1920. (From the College.)

Connelly, The D., Boiler Company, Boilers. Cleveland, Ohio, 1921. (From the Company.)

Cummings Machine Company, Catalogue No. 65 of Foundry Equipment. Minster, Ohio, no date. (From the Company.)

Cutler–Hammer Manufacturing Company, C-H Magnetic Clutches. Milwaukee, Wisconsin, no date. (From the Company.)

Departamento de Agricultura y Trabajo, Circulars No. 41, 42, 43, 44 and 45. San Juan, Porto Rica, 1921. (From the Department.)

Edison Swan Electric Company, Limited, Catalogue Ab.2 of Lighting Accessories. London, England, 1919. (From the Company.)

Foote–Burt Company, Catalogue on Drills. Cleveland, Ohio, no date. (From the Company.)

Gardner Machine Company, Gardner Improved Abrasive Disc. Beloit, Wisconsin, no date. (From the Company.)

Gilfillan Brothers, Inc., Catalogue No. 7, Gilfillan Products. Los Angeles, California, 1920. (From Gilfillan Brothers.)

Griscom–Russell Company, Bulletin 903 and Leaflet No. 6. Philadelphia, Pennsylvania, no date. (From the Company.)

Haiss, George, Manufacturing Company, Inc., Booklet 719 of Haiss Buckets. New York City, New York, no date. (From the Company.)

Hans Renold, Ltd., Chains and the Machine Tool. Didsbury, England, 1921. (From the Company.)

Harrison Safety Boiler Works, Cochrane Separators. Philadelphia, Pennsylvania, 1913. (From the Works.)

Hart Roller Bearing Company, Value *versus* Competition. Orange, New Jersey, 1921. (From the Company.)

Hauser–Stander Tank Company, Wooden Tanks for Every purpose. Cincinnati, Ohio, no date. (From the Company.)

Hayward Company, Pamphlet 617 of Hayward Buckets. New York City, New York, no date. (From the Company.)

Hoffman Specialty Company, Hoffman Venting Valves for Every Service. Waterbury, Connecticut, no date. (From the Company.)

Hunter Saw and Machine Company, Catalogue E of Hunter Saws and Tools. Pittsburgh, Pennsylvania, 1921. (From the Company.)

Ilg Electric Ventilating Company, Universal Blowers and Motor Propeller Fans. Chicago, Illinois, 1921. (From the Company.)

Independent Concrete Pipe Co ··ny, Bulletin No. 9, Reinforced Concrete Pipe. Indianapolis, Indian· ·· ~ ᴗ   (From the Company.)

India Geological S·   ——   ii, Memoir No. 2, The Brachiopoda of the Namyau B· '   ₁ Shan States, Burma. Calcutta, India, 1917. (From the·   ⌡

India Meteor Department, Monthly Weather Review for February and March, ₁ Calcutta, India. (From the Department.)

Institution · Civil Engineers, Minutes of Proceedings with Selected Papers, vol. ccii₂ London, England, 1921. (From the Institution.)

Instituto Geologico de Espana, Boletin Tomo 42. Madrid, Spain, 1921. (From the Institute.)

Johns Hopkins University, Magnetic Rotatory Dispersion in Transparent Liquids, Fluorescence of Mercury Vapor, Air Forces on Circular Cylinders, Axes Normal to the Wind, with Special Reference to Dynamical Similarity, Electric Strength of Air under Continuous Potentials and as Influenced by Temperature. Baltimore, Maryland, 1921. (From the University.)

Klaxon Company, Booklets on Klaxocator System and Intercommunication and Signal Equipment for Ships. Newark, New Jersey, no date. (From the Company.)

Leeds and Northrup Company, Catalogue No. 20 of Galvanometers. Philadelphia, Pennsylvania, 1921. (From the Company.)

Lister, R. A., and Company, Ltd., Catalogue of Oil Engines. Bursley, England, no date. (From the Company.)

Locomotive Feed Water Heater Company, Bulletin 5 of Feed Water Heating. New York City, New York, 1919. (From the Company.)

McIntosh and Seymour Corporation, Achievement in Motorships. Auburn, New York, 1921. (From the Corporation.)

MacLeod and Henry Company, Boiler Setting Fire Brick. Troy, New York, 1921. (From the Company.)

Maryland Academy of Sciences, Bulletins for March and June, 1921. Baltimore, Maryland, 1921. (From the Academy.)

Morris, Herbert, Incorporated, Booklet of Hoists, Trolleys and Cranes. Buffalo, New York, no date. (From the Company.)

National Commission of Fine Arts Ninth Report, July, 1919, to June, 1921. Washington, District of Columbia, 1921. (From the Commission.)

National Tube Company, Seamless Steel Tubes and Their Making. Pittsburgh, Pennsylvania, 1920. (From the Company.)

New Zealand Department of Mines, Geological Survey Branch Bulletin No. 23. Wellington, New Zealand, 1921. (From the Geologist.)

New Zealand Institute, Transactions and Proceedings, vol. liii. Wellington, New Zealand, 1921. (From the Institute.)

Nordberg Manufacturing Company, Machinery for the Mining Industry. Milwaukee, Wisconsin, no date. (From the Company.)

Philadelphia Bureau of Surveys, Annual Reports for 1919 and 1920. Philadelphia, Pennsylvania. (From the Bureau.)

Pollock and MacNabb, Ltd., Catalogue of Machine Tools. Bredbury, England, no date. (From the Company.)

Pratt and Cady Company, Incorporated, Catalogue No. 6, Valves. Hartford, Connecticut, 1921. (From the Company.)

Providence Athenæum, Eighty-sixth Annual Report. Providence, Rhode Island, 1921. (From the Athenæum.)

Rapid Electrotype Company, from Xylographs to Lead Molds, A.D. 1440–A.D. 1921. Cincinnati, Ohio, 1921. (From the Company.)

Reading Valve and Fittings Company, Flanges and Fittings. Reading, Pennsylvania, 1920. (From the Company.)

Royal Society of South Australia, Transactions and Proceedings, vol. xliv.
Adelaide, South Australia, 1920. (From the Society.)

Scovill Manufacturing Company, Tube Facts. Waterbury, Connecticut, no
date. (From the Company.)

Sheffield Twist Drill and Steel Company, Ltd., Catalogue of Twist Drills.
Sheffield, England, no date. (From the Company.)

Smithsonian Institution, Report on the Progress and Condition of The United
States National Museum. Washington, District of Columbia, 1921. (From
the Institution.)

Stanford University, Register 1920–1921. Stanford University, California,
1921. (From the University.)

Stanley Works, Catalogue of Wrought Hardware. New Britain, Connecticut,
no date. (From the Works.)

Station Biologique, D'Arachon, Bulletin 18. Bordeaux, France, 1921. (From
the Station.)

Sterling Wheelbarrow Company, Catalogue No. 32. Milwaukee, Wisconsin,
no date. (From the Company.)

Stokes, Francis J., A Treatise on Tablet and Pill Coating. Philadelphia, Penn-
sylvania, no date. (From the Author.)

Superheater Company, Instruction for Operation and Maintenance of Boiler
Feed Pumps. New York City, New York, no date. (From the Company.)

Swedish Chamber of Commerce of the United States, Iron and Steel in Sweden.
New York City, New York, no date. (From the Chamber.)

Tate Electrolytic Textile Processes, Mildew Proof Canvas. New York City,
New York, 1921. (From the Company.)

Truscon–Steel Company, Booklet of Truscon Steel Sash. Youngstown, Ohio,
no date. (From the Company.)

Tulane University of Louisiana, Registers for 1915 to 1921, inclusive. New
Orleans, Louisiana. (From the University.)

Uehling Instrument Company, Bulletins Nos. 220 and 221 on Chimneys. Pater-
son, New Jersey. (From the Company.)

Union University, Medical Department Announcement for 1921–1922. Albany,
New York, 1921. (From the University.)

United States Bureau of Education, Report of the Commissioner of Education
for 1921. Washington, District of Columbia, 1921. (From the
Commissioners.)

United States Army, Report of the Chief of Engineers, Parts i and ii. Wash-
ington, District of Columbia, 1921. (From the Chief.)

United States Navy Department, Annual Reports of the Secretary of the Navy,
Surgeon General of the Navy and Paymaster General of the Navy. Wash-
ington, District of Columbia, 1921. (From the Department.)

U. S. Ordnance Department, Manufacture of Optical Glass and Optical Systems.
Washington, District of Columbia, 1921. (From the Department.)

University of Illinois, Soil Report No. 19. Urbana, Illinois, 1921. (From
the University.)

University of Pittsburgh, General Catalogue 1921–1922. Pittsburgh, Penn-
sylvania, 1921. (From the University.)

University of Wisconsin, Announcements 1920–1921 and Publications of the Washburn Observatory, vol. x, part 4. Madison, Wisconsin, no date. (From the University.)

Vacuum Oil Company, Stationary Steam Engines. New York City, New York, 1921. (From the Company.)

Vassar College, Fifty-seventh Annual Catalogue, 1921–1922. Poughkeepsie, New York, 1922. (From the College.)

Vogt, Henry, Machine Company, Bulletin R-E 2. Louisville, Kentucky, no date. (From the Company.)

Vulcan Soot Cleaner Company, Bulletins Nos. 534, 541, 547, 548, 550, 552 and 556. Du Bois, Pennsylvania, 1920. (From the Company.)

Walker, James, and Company, Limited, Packings and Jointings. New York City, New York, no date. (From the Company.)

Washington University, Sixty-fifth Annual Catalogue. St. Louis, Missouri, 1922. (From the University.)

Whitney Manufacturing Company, Booklets on Driving Chains. Hartford, Connecticut, 1921. (From the Company.)

Whitworth, Sir W. G. Armstrong, and Co., Ltd., Armstrong Whitworth Locomotives. London, England, no date. (From the Company.)

Youngstown Boiler and Tank Company, Bulletin 400. Youngstown, Ohio, 1921. (From the Company.)

BOOK NOTICES.

Petroleum. A treatise on the geographical distribution and geological occurrence of petroleum and natural gas, etc. By Sir Boverton Redwood, Baronet. With a foreword by Sir Frederick W. Black, K.C.B. 4th edition, reset throughout. In three volumes, with plates, numerous illustrations and many maps. Philadelphia, J. B. Lippincott Company, $21.00 net.

The author of this book has been for many years one of the foremost authorities in the field to which it is devoted. The name of Redwood is familiar to all who are interested in liquid or gaseous fuels. The death of the author at a comparatively early age occurred after the material for this edition had been largely arranged and a biographic note by Sir Frederick W. Black, gives interesting accounts of Redwood's work and the important part that he has taken in the study and development of the science and technology of petroleum and allied products. Redwood's friends, as Black states, will be pleased to know that he lived until the " oil age " was well developed, and quotes Curzon's phrase that Great Britain and her allies had " floated to victory on a sea of oil."

Oil has often been spoken of as a quieter of disturbances. To pour oil on troubled waters has been a proverbial expression for a long time, but it seems that at present, oil is rather troubling the waters of diplomacy than pacifying them. A lull in the agitation has seemingly been due to the interest the world has been taking in the conference at Washington, but after the problems are for the time settled there, and diplomats return to their own lands, it is probable that mercantile interests, especially in connection with the oil-burning ship and the internal combustion engine, will arise and be the subject of correspondence

pourparlers, protests, protocols and other apparatus of international manipulations. There is no doubt that Great Britain has been aiming to secure a large control of oil production. For this action no one can blame British statesmen, seeing how dependent the nation is on efficient ships and control of the sea. Redwood, indeed, held that whatever might be the applicability of oil in general, it is a necessity for the British navy. He predicted that oil will transform ocean traffic, and that new forms of oil engines will enable the submarine to be used as a merchant vessel.

Turning to the book itself, we find, as would be expected, that it contains an enormous amount of detailed information covering every phase of the question. Many hands have been active in bringing up the sections to meet present knowledge and requirements. All those who have thus aided are duly acknowledged in the preface. The work begins with a historical introduction, in which the earliest definite references to the materials are collected, but such references are not only scanty, but more or less uncertain on account of the lack of definite knowledge of the meaning of ancient words. Some of the solid substances consisting largely of hydrocarbons and their oxidation products were certainly used in very ancient times. Indeed, we have in Babylonian bricks an account of the building of the ship for use during the flood, in which the complaint is made that seven barrels of pitch were charged for when only three were used. After the historical note, the localities in which petroleum and natural gas were found are described, and a map of the world on Mercator's projection shows at a glance the distribution of these fields. Of course, these indications cover only the points at which such deposits have been found. Many other localities probably exist, for the discovery of oil and gas has often been somewhat catastrophic.

The question of the duration of oil-supply is a momentous one, and some space is given to the discussion of it. It is there stated that the production of oil and gas is still going on in some places, but the districts which are being most largely worked are not being recuperated in appreciable amount, and when they are exhausted will be permanently barren. The strata yielding oil and gas are geologically identical, the latter accumulating in the domes or arches in the deposits. The most productive wells in the United States obtain gas from very old rocks, but the Russian yields are from later geologic formations.

The origin of petroleum and gas has been extensively discussed. The Engler–Höfer theory which ascribes the production to the decomposition, in place of the fatty matters of marine organisms—animal and vegetable—at one time quite popular, is stated to be apparently losing support.

The first volume closes with accounts of the physical and chemical properties of the products, in which an enormous amount of statistical material is accumulated. The second volume takes up the methods of obtaining and refining the materials and the methods of transport, storage and distribution. Sixty-six pages are devoted to the shale-oil and allied industries, a welcome and important chapter in view of the attention that is now being given to these sources of liquid and gaseous fuels.

The analytical methods and the practical applications are included in the

third volume, which contains also a summary of the laws and regulations and extensive statistics of production, with data concerning the duties levied on the raw materials and their products. A local flavor is given by two pages devoted to the regulations for motor boats on the Thames. A bibliography of 261 pages and an index of 35 closely, but clearly, printed pages show the work that has been done in perfecting this book. The many forms of motors and other apparatus adapted to the use of these fuels are described in detail, an appendix giving an account of the recently introduced " Bonecourt " method, the joint invention of Professor Bone and Mr. M'Court, and of the two methods which have been devised therefor.

The work is a magnificent treatise upon one of the most important industrial questions, and reflects great credit on its original author, as well as on those who have carried on his work. The mechanical execution deserves high praise, the text, tables, illustration and maps being all excellent. The edition maintains the status which the work acquired when first issued, namely that of leader in its field.

HENRY LEFFMANN.

REVUE D'OPTIQUE, THÉORIQUE ET INSTRUMENTALE, Année 1, No. 1.

This review of optical science is essentially the successor of the *Revue Générale d'Optique et de Mécanique de Precision,* but it has been deemed advisable to make an entirely new start, and to increase the efficiency of the publication. This change has been made because the journal now goes under the care of a newly formed " Institute of Optics," an organization duly authorized by the Minister of Public Instruction and, in accordance with French law, declared to be of public advantage.

Dr. Charles Fabry, well known in the field to which the journal is devoted and who received the Franklin medal for his researches in spectroscopy, is one of the most active members of the new society, and will take an important part in its publications. As Major Fabry, he came to the United States in the early summer of 1917 to assist our government in those features of war which require modern scientific methods, and his mission was of great use. Fabry's work in connection with Michelson, Perot and Benoit led to the development of a method by which the length of the standard meter-bar was fixed by means of light waves.

The new journal begins under very favorable auspices and will give steadily interesting and valuable contributions in its field. It will appear monthly in octavo form of about 48 pages. The first number contains a paper by Fabry and Buisson on a " Universal Screenless Photometer," another by Chrétien on " Newtonian and Aplanatic Telescopes " and a report on progress by Guadet, the especial subject being the use of the astronomical interferometer. Other articles are: Apparatus presented, a bibliography of current literature and a discussion of the commercial activity of Germany in optical apparatus. Among the " apparatus presented " is to be noted a new stereoscopic camera. French photographers are giving a great deal of attention to this field of photography, which at present attracts but little attention in America, though was once very popular.

HENRY LEFFMANN.

PRÉCIS D'ARITHMÉTIQUE. Par J. Poirée. 8vo., paper, 62 pages. Paris, Gau-
    thier-Villars et Cie. Price 7f, 50.

Elementary arithmetic is a good introduction to the study of mathematics,
because it gives the beginner, under form of concrete examples, the methods of
reasoning ranging from the simplest to the most complex. Notwithstanding
such advantage, the field is much neglected by the generality of pupils, for
which they are, perhaps, not wholly to blame, since authors see the more impor-
tant and difficult phases and do not wish to leave these in the shadow, thereby
overlooking the more elementary but simpler phases of the reasoning. M.
Poirée has been able to avoid this difficulty and has condensed in a limited
number of pages all that belongs to the classic course in this field, and has
added a chapter which is an introduction to the theory of numbers.

Eliminating all that is not entirely indispensable, the author passes rapidly,
but with care, to principles of enumeration, the fundamental operations,
division, primary numbers and puts the theorems in a logical order. The treat-
ment of fractions affords an opportunity to introduce a dissertation on the
theory of limits, that beginners find difficult to understand. In connection
with the section on square root he discusses the subject of irrational numbers.
These different sections are fully illustrated with examples. The work is,
therefore, a useful contribution to this field.

<div align="right">HENRY LEFFMANN.</div>

NATIONAL ADVISORY COMMITTEE FOR AERONAUTICS.

Report No. 113, Tests on Air Propellers in Yaw, by W. F. Durand and
E. P. Lesley. 37 pages, diagrams, quarto. Washington, Government Printing
Office, 1921.

This report contains the results of tests to determine the thrust (pull) and
torque characteristics of air propellers in movement relative to the air in a
line oblique to the line of the shaft, and specifically when such angle of obliquity
is large, as in the case of helicopter flight with the propeller serving for both sus-
tentation and traction.

Report No. 116, Applications of Modern Hydrodynamics to Aeronautics, by
L. Prandtl. 61 pages, illustrations, diagrams, quarto. Washington, Govern-
ment Printing Office, 1921. This report gives rather briefly in part one an intro-
duction to hydrodynamics which is designed to give those who have not yet
been actively concerned with this science such a grasp of the theoretical and
underlying principles that they can follow the subsequent developments. In part
two there follows a separate discussion of the different questions to be con-
sidered, in which the theory of aerofoils claims the greatest portion of the
space. The concluding portion is devoted to the application of the aerofoil theory
to screw propellers.

PUBLICATIONS RECEIVED.

Analogies Mécaniques de l'Électricité, par J. B. Pomey. 150 pages, illustrations, 8vo. Paris, Gauthier-Villars et Cie., 1921. Price 15 francs.

U. S. Department of Agriculture, Bulletin 1025. Studies in the clarification of unfermented fruit juices, by Joseph S. Caldwell. 30 pages, 8vo. Washington, Government Printing Office, 1922.

U. S. Bureau of Mines: Technical Paper No. 284, Coal and Coke Mixtures as Water-gas Generator Fuel, by W. W. Odell, Illinois coal mining investigations coöperative agreement. 32 pages, plates, 8vo. Washington, Government Printing Office, 1921.

National Advisory Committee for Aeronautics: Technical Notes, No. 78, Impact Tests for Woods, by Bureau of Standards. 17 pages, diagrams, photographs, quarto. No. 80, The Deadweight of the Airship and the Number of Passengers that Can Be Carried, by Colonel Crocco. Extracts from the *Transactions of the Aeronautical Experimental Institute,* Rome, Italy. 20 pages, diagrams, quarto. Technical Notes, No. 81, Langley Field Wind-tunnel Apparatus. Part I, Regulators for Speed of Wind-tunnel Drive Motor. Part II, A Vernier Manometer with Adjustable Sensitivity, by D. L. Bacon. 9 pages, illustrations, quarto. Washington, The Committee, 1922.

The Application of the Principles of Efficiency to the Teaching of Chemistry, by J. Norman Taylor. 10 pages, 8vo. Reprinted from *School Science and Mathematics,* December issue, 1921. Chemical Nomenclature and Pronunciation, by J. Norman Taylor. 2 pages, 8vo. Illustration of Molecular Motion, by J. Norman Taylor. 2 pages, 8vo. Reprinted from June, 1920, issue *School Science and Mathematics.* The Utility of Mineralogy in Elementary Chemistry by J. Norman Taylor. 2 pages, 8vo. Reprinted from May, 1921, number of *School Science and Mathematics.*

New Potash Areas in the United States. (*Press notice, U. S. Geo. Sur.*)—The potash problem became acute during the war and led to energetic search for native sources, with some satisfactory results. In boring for oil recently in Texas, potash deposits have been found at points considerably distant from the localities known hitherto. The data at hand, however, are not sufficient to determine positively the thickness of the beds. The well-drillers, being interested only in the oil, have not been attentive to the preservation of the samples of the strata encountered, but the likelihood of the presence of potash will cause them to be more attentive in future drillings. Some of the samples already submitted have shown high potash content, but more extended examinations, which are now in progress, will give more definite information.

H. L.

CURRENT TOPICS.

Duration of Impact of Bars. E. W. TSCHUDI. (*Phys. Rev.*, Dec., 1921.)—Let two metal bars approach each other and collide. After an instant they will separate. How is this brought about? There are two explanations offered. According to one a compressional wave starts in each bar from the end in contact, travels to the distant end, is there reflected as a wave of tension, comes back to its starting point and pulls its bar away from the other. By this theory the time the bars remain in contact should be in proportion to the length of the shorter bar, because the wave must go to the distant end and return before the bars can separate. Further, the velocities with which the bars are moving at the moment of impact should make no difference as they will not affect the velocity of the wave in the bars. The present experimenter finds not alone that the time of contact is not proportional to the length of the shorter bar but also that velocity before impact does affect the duration of contact. These negative results seem to disprove the theory stated above. Further evidence in the same direction was obtained by the use of model bars of equal length made up of steel springs loaded in order to reduce the speed of wave propagation. The progress of the compressional wave could be followed with the eye. It was seen that this wave had traversed only about one-third of the length of each bar by the time that they rebounded from one another.

The second theory, due to Hertz, relates primarily to the impact of curved surfaces. It assumes that the effect of the collision is localized near the place of contact. "The pressure gradually increases until the bodies are brought to rest and then decreases until they are separated again." Measurements made of the duration of contact of metal spheres verify this theory and encourage the author to adapt it to the case of impinging cylinders.

When a cast-iron sphere, 7.62 cm. in diameter, struck with a speed of 96 cm. per sec. a like sphere at rest, the contact lasted .00033 sec. When the velocity was 14 cm. per sec., contact lasted .00058 sec. When a cylinder of hot-rolled machinery steel, 2.86 cm. in diameter and 15.9 cm. long, moving with a speed of 90 cm. per sec., struck an equal cylinder at rest the contact lasted .0002 sec. Upon reducing the original velocity to one-fifth of its former value, the time of contact increased by about 60 per cent.

When one piece of metal came into contact with the other the charging circuit of a condenser was closed. The charge imparted to it depended on the duration of contact. The condenser was later discharged through a ballistic galvanometer, from whose fling primarily the charge and secondarily the duration of contact was derived.

<div align="right">G. F. S.</div>

Annual Report of the Director of the Department of Terrestrial Magnetism for 1920. Carnegie Institution.—Under the direction of Dr. L. A. Bauer the magnetic survey of the earth proceeds. On the sea the *Carnegie* has, no doubt, long since completed her latest cruise of 62,000 miles after winding her sinuous way across the Atlantic, the Pacific and the Indian Oceans. If the voyages of her scientific predecessor, the *Galilee,* are included, the total distance covered is greater than the distance from the earth to the moon by some three circumferences of the earth. The change of the vessel's engine so that it operates on gasoline instead of on producer gas has proved satisfactory. It has been possible to furnish results of the ocean survey to chart makers within two or three months of the date of the observation. In addition to the magnetic work on board the *Carnegie* observations on atmospheric refraction, on the occurrence of thunder at sea, on St. Elmo's fire, and on ocean currents as well as on the following features of atmospheric electricity, potential-gradient, ionic content, conductivity, penetrating radiation and radioactive content of the atmosphere were made.

On land Mr. Frederick Brown successfully conducted expeditions for magnetic survey through Cameroon to Lake Tchad and from the west coast of Africa to Portuguese East Africa and Madagascar. At certain places he connected with former surveys, thus rendering possible the determination of secular changes in the earth's magnetism. In the winters of 1918–1920 Captain Amundsen secured a series of magnetic measurements at forty places on the coast of Siberia. In all, from 1905 to 1920, observations have been made at about 4000 stations on land, in 121 countries and on the islands of the sea. To do this observers have traveled a million miles.

It must not be inferred that all the work of the Department is done in the field. A great part is carried on in the Laboratory of Terrestrial Magnetism in Washington. Here are focused the results of the survey and here they are interpreted and applied to the solution of problems.

Every year furnishes additional reason for rejoicing that so great a scientific institution exists among us.

G. F. S.

Positive Ray Analysis of Lithium and Magnesium. A. J. DEMPSTER. (*Phys. Rev.,* Dec., 1921.)—Atoms with a positive charge acquire a velocity by falling through a difference of potential. A magnetic field bends into a semicircle a narrow beam of such moving atoms. The mass of the atom can be computed from the fall of potential, the radius of the circle, the strength of the applied magnetic field and the elementary electric charge. Two isotopes of lithium were identified with atomic weights of 6 and 7, their relative proportions changed from time to time. Magnesium gave three isotopes with atomic weights of 24, 25 and 26.

G. F. S.

On Majorana's Theory of Gravitation. H. N. RUSSELL. (*Astrophys. J.*, Dec., 1921.)—From the result of certain pendulum experiments Majorana was led to conclude that a mass of lead exerted less gravitational force when surrounded by a jacket of mercury than when not so surrounded. To account for this he proposed a law of gravitation which is the same as Newton's law when no matter exists along the line joining the two attracting particles, but which, in the case that matter does there exist, has an added factor of exponential form that causes a reduction of the calculated force between the two particles. The Princeton astronomer examines the consequences of this law when applied to the solar system. If the presence of matter between two bodies does diminish their gravitational attraction, then the attraction of the central parts of a sphere is reduced by the presence of the surface portions and the mass of the sphere as calculated from its attraction on other bodies will be actually less than its real mass. In the case of the sun its apparent mass would be only .33 of its real mass, the correctness of Majorana's constant of gravitational absorption being assumed. For the earth the corresponding fraction is .981, for the moon .997. We cannot disembowel the moon or a planet to find which law, Newton's or Majorana's, gives the correct value of the mass, but an application of Kepler's Third Law, shows that the proposed law carries implicitly with it other distances of the planets from those accepted on the basis of Newton's law. The mean distance of Jupiter from the sun would be 1.04 per cent. less than the generally accepted value, and the planet's longitude would not agree with its predicted value. In the instance of the moon the new law would require the application of a different accelerating force. " Its introduction would play utter havoc with the whole lunar theory." " We are forced therefore to the conclusion that upon the hypothesis that there exists an absorption of gravitational force in matter, without change in its inertial mass, the coefficient of absorption cannot exceed one ten-thousandth of that derived by Majorana from his experiments, and must be hopelessly beyond the reach of investigation in the laboratory."

G. F. S.

The Nitrogen Problem.—The possibility of recovering a greater proportion of the nitrogen from coal is the subject of a paper by GIANOLI in the *Giornale di Chimica,* who, among other matters, reviews the technical difficulties relating to coal distillation in the presence of alkali-metal chlorides. Gianoli says that to carry out such a method, extensive alterations would be needed in the gas plants, the cost of which would be likely to exceed the profits of the procedure. The liability to the production of corrosive volatile chlorides must also be considered. The coke would contain much mineral matter. The process seems best suitable for a low-grade gas plant. Incidentally, the question of utilizing the nitrogen oxides produced in internal combustion engines is examined.—*Chem. News.*

H. L.

Research Graduate Assistants in the University of Illinois.— The Director of the Engineering Experiment Station of the above University invites applications for positions under the auspices of the station. The University maintains fourteen Research Graduate Assistantships in the Engineering Experiment Station. Two other such assistantships have been established under the patronage of the Illinois Gas Association. These assistantships, for each of which there is an annual stipend of $600 and freedom from all fees except the matriculation and diploma fees, are open to graduates of approved American and foreign universities and technical schools who are prepared to undertake graduate study in engineering, physics, or applied chemistry. H. L.

Detection of China Clay by Means of the Microscope.—China clay is used to adulterate fine meals. The British "Government Chemist" has devised the following procedures for the detection of the presence of this adulterant (*Analyst*, 1921, xlvi, 496). The fine dust, which passes through a sieve with 100 meshes to the inch, is ignited and the residue is examined microscopically by means of polarized light and crossed Nichol prisms. Or the sample is shaken with ether to obtain an ethereal suspension of the kaolin and the starch. The ethereal layer is decanted; the ether is evaporated; the residue is ignited; and the ash is examined microscopically. If it consists chiefly of fine crystals of feldspathic origin, kaolin was present. J. S. H.

Precipitation of the Sulphide from Solutions of Pentavalent Arsenic.—J. H. Reedy, of the University of Illinois (*Jour. Am. Chem. Soc.*, 1921, xliii, 2419), states that the presence of a soluble iodide, such as ammonium iodide, greatly accelerates the precipitation of arsenic as its sulphide, when hydrogen sulphide is passed into the aqueous solution of an arsenate acidified with hydrochloric acid. The iodide reacts with the arsenic acid to form arsenious acid and iodine. The hydrogen sulphide reacts with this iodine to produce hydriodic acid; and the entire cycle is repeated. The hydrogen sulphide also precipitates arsenious sulphide from the resulting solution of arsenious acid. J. S. H.

LONG DISTANCE RADIO COMMUNICATION.[*]

BY

L. W. AUSTIN, Ph.D., D.Sc.

Head U. S. Naval Radio Research Laboratory; Bureau of Standards,
Washington, D. C.

THE distances which can be covered in radiotelegraphy have in the past always been limited mainly by the sensitiveness of the detecting apparatus, and only secondarily by the transmitting power. In the early days, when coherers were used, reliable transmission was confined to a few miles. With the discovery of the electrolytic and crystal contact detectors, the reliable range could be counted in hundreds of miles, and a somewhat uncertain communication existed across the Atlantic Ocean. This was the condition at the beginning of 1914, when the recent discovery that the de Forest three electrode audion (electron tube) was capable of producing oscillations opened a new era for radio communication. Up to that time, spark transmitting apparatus had been generally used both for the short range ship installations and for the few high-power long-distance stations then existing. The Poulsen arc giving continuous waves, in distinction from the damped wave trains from the spark, introduced about 1908, had been gradually developed so that powers of 50 KW. or more had been obtained, and a beginning had been made in the construction of high-frequency alternators, also giving undamped waves. The advantages of continuous waves, in distinction from damped

---

[*] Presented at a meeting of the Electrical Section of The Franklin Institute held Thursday, February 2, 1922.

waves, for high-power transmission were already well recognized. It was realized that, in addition to the increased selectivity in reception, the antennas required for a given transmitting antenna current could be made much smaller if continuous waves were used, and that the limitation on the possible wave-length, which existed in the case of damped waves, was removed by the use of continuous waves. The wave-length limitation for damped waves is due to the fact that the duration of the wave trains for a given decrement becomes greater as the wave-length is increased, that is, as the wave frequency is diminished, so that for a given spark frequency the successive trains approach each other and eventually overlap, thus destroying the clearness of the signal. For desirable spark frequencies, this automatically set a limit of four or five thousand metres on the wave-length.

Up to 1914 there had been no very satisfactory methods of receiving continuous waves. The customary spark receiving method could not be used because the waves were no longer divided up into trains of audible frequencies. Poulsen had placed a kind of circuit breaker, which he called a tikker, in the telephone circuit of the receiver for the purpose of breaking up the waves, and this had been improved upon and was quite generally used though far from satisfactory, since the note of the signals as heard in the telephones was not musical and could not be easily distinguished from the noises produced by atmospheric and induction disturbances. Several years before even the first experiments of Marconi, Tesla gave a marvellous series of lectures in which he pictured a system of radiotelegraphy which contained, in principle at least, almost everything which would be required for our present day radio transmission excepting the detectors and amplifiers. In these lectures Tesla proposed to receive continuous waves by making use of the audible frequency beats between two systems of waves sent out from the transmitting station at slightly different frequencies. Fessenden improved on this idea by placing the source of the second system of waves for the production of beats at the receiving station, and apparatus was actually constructed by his company in which a small arc transmitter was made to act on an ordinary spark receiving set so that undamped signals could be received on the beat principle. This arrangement, however, proved to be rather unmanageable, and it is doubtful if the beat method would have supplanted the tikker if it had not

been for the discovery of the oscillating electron tube. Like so many of the great discoveries in the history of science, the idea seems to have occurred almost simultaneously to a number of workers that the de Forest electron tube could be made a source of electrical oscillations. And nearly at the same time (1913), E. H. Armstrong in this country, A. Meissner in Germany, and H. J. Round in England, brought the idea into practical form.

Since the electron tube is able to act as a detector, and at the same time furnish its own oscillations, it at once solved the problem of beat reception in the simplest possible way.[1] With the discovery, at about the same time, that the tube was capable of amplifying weak electrical currents at either radio or audible frequencies, and that by connection of the tubes in cascade this amplification could be increased to almost any desired extent, the art of modern oral radio reception may be said to have come completely into being. The new beat method of reception has several advantages over the older method in which the electrolytic, crystal contact detector, or the non-oscillating audion were used. First, by changing the frequency of the local oscillations the note of the beats can be varied to suit the operator's ear. Second, every interfering station which is not exactly on the wave-length of the station being received has its distinctly different note. Third, the formation of beats in the receiving circuit results in currents in the receiving telephones proportional to the high-frequency currents in the antenna, while in the old detectors the telephone currents were proportional to the square of the antenna currents. The square law of response results in strong signals being very loud and weak signals very weak. In the case of atmospheric disturbances with their strong momentary peaks of intensity, this frequently results in the drowning out of the somewhat weaker signal which with undamped waves and beat reception could be easily read. Experience shows that under the ordinary conditions of atmospheric disturbance, it requires from two to four times as much current in the sending antenna to give a readable signal in the case of damped waves as with continuous waves and beat reception.

---

[1] For certain purposes, and especially when radio frequency amplification is used, it is found best to separate the two functions, using one tube as a detector and another one inductively coupled to the circuit as an oscillator for the production of the beats.

Recent development in transmitters has gone along three independent lines, the arc, the high-frequency alternator, and the electron tube generator. The use of the arc received a great impulse at the time of the discovery of the oscillating tube as a detector, and in spite of certain inherent disadvantages, it has come into increasing use on account of its great simplicity and reliability.

Among high-frequency alternators there are three types in use, of these the Alexanderson is employed by the Radio Corporation of America which has put them into a number of high-power stations. In France the Latour machine is coming into prominence, while in Germany the Telefunken machine is the only one of any importance, as the Goldschmidt type is, I believe, no longer used. All of these three machines are of the inductor type, the Alexanderson and the Latour machines producing the required radio frequency directly, while the Telefunken runs at slower speed, has fewer poles, and steps up the frequency by means of frequency doublers.

The third method of producing high-frequency electrical oscillations, that is, by means of the electron tube, while very commonly used for small powers, is only beginning to invade the high-power field. The English Marconi Company has recently equipped its Clifden station in Ireland with an electron tube set for communication with Nova Scotia, and its performance is stated by the company to have been extremely satisfactory.

The advantages and disadvantages of the three methods of generating continuous waves may be enumerated somewhat as follows:

The advantages of the arc are low initial cost, simplicity of manipulation, flexibility in changing wave-length, reliability, and cheapness of upkeep. Its disadvantages are a somewhat low overall efficiency, and a somewhat impure wave which gives rise to harmonics and other disturbing emissions which cause disagreeable interference for stations working at short wave-lengths. The harmonics can, however, be largely eliminated by coupling the arc inductively to the antenna.

The alternators have the advantage of higher over-all efficiency than the arc, a purer wave, and perhaps the capability of being built in larger units and of being used in parallel for the production of very high powers. Their disadvantages are high

initial expense, and less rugged construction than the ordinary types of electrical generators. The Alexanderson and the Latour alternators have little flexibility in wave changing, while the Telefunken is limited to multiples of its initial frequency.

While our knowledge of the performance of high-power electron tube sets is very limited, they have certain qualities which seem to make them somewhat hopeful rivals of the arc and alternator. Their advantages are the highest over-all efficiency (70 per cent. to 90 per cent.), complete flexibility of wave-length change, low initial cost, and great purity of note in received signal. The disadvantages are a probable high cost of upkeep, harmonics which are considerably more objectionable than those of the alternator, and the fact that up to the present, at least, it has not been found possible to produce them commercially in units of a normal output greater than about 7 or 8 KW., although it is said that experimental tubes with an output of more than 30 KW. have been constructed.

The antennas which have been used in high-power stations are of widely different forms. It has been believed by some engineers that the Marconi bent antenna, having a length of many times its height, showed marked directive qualities so that signals could be sent in the favorable direction with much less power than with a symmetrical antenna. But the general feeling now seems to be that the directivity of the long antenna is negligible for the wave-lengths used in long-distance transmission, and that as long as the antenna has sufficient capacity for the desired currents without objectionable voltage, and has sufficient height above the ground, its shape is of no importance.

The portions of the transmitting system thus far described, the generator and the antenna, may be considered satisfactory from the efficiency standpoint, but we now come to the weak link in our transmitting system, that is, the antenna ground. In short wave stations where the power consumed in radiation is considerable, the resistance of the ground system is not of such great importance; but for long distance, long wave stations, it forms one of the two most pressing problems of radio.

Expressed in resistance, the power consumed in radiation at Annapolis, for example, at a wave-length of 17,000 metres is 0.07 ohm, while the wasteful resistance amounts to 1.6 ohms, of which a little more than 1.0 ohm is in the ground system, that is,

we have a radiation power efficiency of only 4.1 per cent. Now the power cost at a station like Annapolis amounts to approximately forty thousand dollars a year. Therefore if the ground resistance could be obliterated and the cost reduced to approximately one-third of its present amount, it would be well worth while. Then by perfectly possible reductions in other losses, the radiation efficiency could be brought to about 25 per cent., a fairly respectable figure.

Mr. Alexanderson, of the Radio Corporation, has succeeded in making a marked improvement in ground resistance in many of the Radio Corporation's stations having antennas of the long Marconi type, by introducing separate connections between the antenna and the ground at a number of points along the length of the antenna, thus dividing the flow of current and diminishing the distance which the current is compelled to traverse in the poorly conducting earth. At New Brunswick this system has reduced the antenna resistance from 3 ohms to approximately 0.25 ohm. It is, however, apparently only applicable to long, narrow antennas. It somewhat reduces the effective height, and since each of the down leads must be separately tuned, makes wave changing and retuning complicated. Very recently Doctor Meissner, of the German Telefunken Company, has announced even greater success in ground resistance reduction, which has, however, up to the present been tried out only on a small model antenna. According to Doctor Meissner's plan, buried ground wires are placed under the antenna, distributed in such a way that the amount of current collected in each ground unit is proportional to the strength of the electric field of the antenna in the given position of the unit. Return wires from the ground units are then brought back, supported on stakes to the foot of the down lead. In this way the current is taken from the ground almost as soon as it enters it, and the earth resistance is thus reduced to a minimum. By this method Doctor Meissner claims to have reduced the earth losses to approximately 0.1 ohm, and as the ground resistances of large antennas have always been found to be less than those of small ones, there seems to be reasonable hope that this radio problem will soon be solved, at least for antennas of the symmetrical types.

Important as the problem of ground resistance is, in the mind of the radio engineer it sinks into insignificance compared with

the supreme radio problem of the elimination of atmospheric disturbances, for on the solution of this problem the whole future of long distance radio depends. If we were freed from these disturbances we would have perfect communication with Europe, with small stations of only two or three KW., since electron tube amplifiers enable us to amplify signals to almost any extent desired, while under existing conditions stations even of a thousand KW. give far from perfect communication. I have been told that during the whole of last July the communication between two of the trans-Atlantic stations, which are considered among the most reliable, was so poor that only 23 per cent. of the words sent were successfully received.

During the last ten years a vast amount of effort has been spent on the disturbance problem. In my own laboratory alone more than one hundred distinct circuits and other devices have been tried, but for the most part with only mediocre success. It was early found that an antenna circuit of large inductance and small capacity was relatively better for receiving through disturbances than an antenna with the opposite characteristics, but the improvement due to this method is but slight. More recently it has been discovered that by the use of closed coil antennas or by the use of buried wires, the signal disturbance ratio may be improved from two to four times. The audio frequency tuning of the circuit containing the telephones also gives some improvement in the signal disturbance ratio, and is of value in reception when the incoming signals are nearly readable, but none of these methods is of any avail against such disturbances as frequently interrupt our communication from Europe during the summer months. The first substantial improvement in reception of weak signals through heavy summer disturbances resulted from the discovery during the war that the larger part of our worst disturbances came in general from the southwest, and thus by the use of a unidirectional antenna system, adjusted to receive from the northerly and easterly direction, it has been found possible at times to receive weak European stations through the most violent disturbances. These directive systems are usually made up of an ordinary antenna combined with a directive antenna such as a closed coil or a buried wire. These last receive most strongly in the direction of their length and not at all at right angles. The reception curve for the coil is shown at AA' in Fig. 1. When combined with the ordinary

antenna, which has a reception curve in the form of a circle, the combination gives a heart-shaped curve as indicated in the figure. That is to say, there is a direction just opposite the direction of maximum reception where the reception is zero. Unfortunately, however, on the Atlantic coast the disturbances at a given time do not always come from the same direction, and under these conditions our directive systems, assailed from several directions at once, no longer avail. There are, however, some favored spots on the earth where the disturbances always seem to come from the same point, so that for the reception from stations lying in a direc-

FIG. 1.
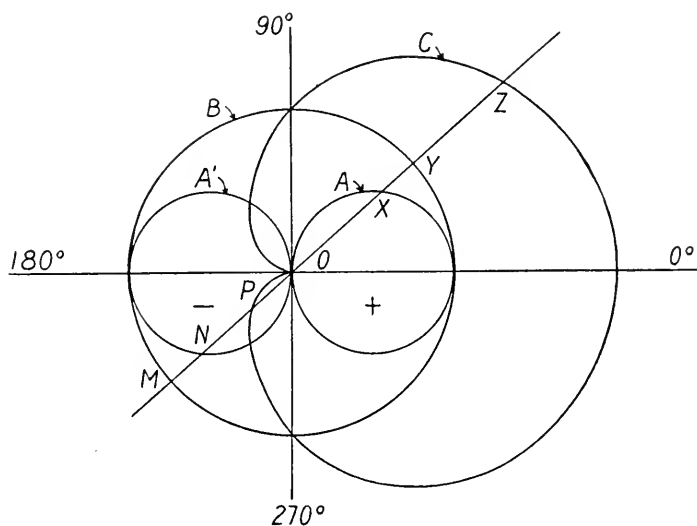
Coil and antenna reception curves.

tion not too near the direction of the disturbance centre, the problem may be considered to be almost solved.

Two such receiving stations have been found, one at Goat Island, in San Francisco Bay, and the other at North Island, opposite San Diego, while it is very possible that similar conditions exist along the whole of the South California coast. But it is known that the disturbance immunity disappears as one goes north from San Francisco, since at Astoria and Bremerton the conditions are no more favorable than on the Atlantic coast. At the Goat Island station the introduction of unidirectional reception has made it possible to receive radio traffic from Cavite in the Philippines, more than 6000 nautical miles away, without interruption, except from other causes, during the worst disturbances of the past summer, instead of relaying the traffic through Hono-

lulu, as has always been necessary in the past. The antenna current at Cavite is 200 amperes and the wave-length 12,100 miles.

We do not yet know whether California is unique in possessing disturbances of such sharp directivity, but at any rate nothing of the kind has been observed elsewhere up to the present. It is evidently of the greatest importance to try to discover locations having similar qualities in regions where it is desired to establish receiving stations.

There is another radio problem which, while not as vital for practical communication as those already mentioned, is of con-

FIG. 2.
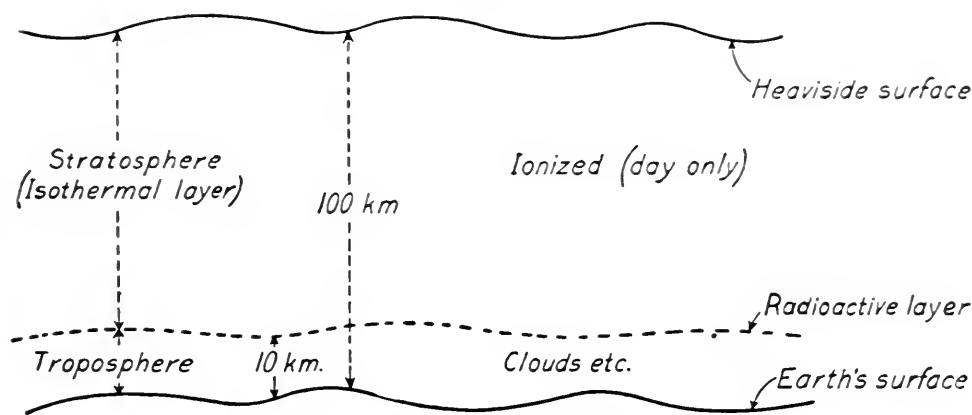
Vertical cross-section of the earth's atmosphere.

siderable theoretical interest, and of importance in the design of stations. This is the determination of the law of the transmission of the electrical waves between the sending and receiving stations.

Observations made by the Navy in 1909 and 1910 between the Brant Rock station and the scout cruisers *Birmingham* and *Salem,* and between Arlington and the *Salem* in 1912, have led to the transmission formula

(1)
$$I_R = 120\pi \frac{I_s\, h_1\, h_2}{\lambda\, d\, R} e^{-\frac{0.0015\, d}{\lambda}}$$

where I_R is the current in the receiving antenna, I_s that in the sending antenna, h_1 the effective height [2] of the sending

---

[2] The transmitting strength of a station, provided a proper wave-length is used for the distance to be covered, is proportional to the product of the effective height of the antenna and the antenna current, usually expressed in amperes and metres. Roughly, the effective height may be taken to be 60 per cent. of the mast height. The rating, so often used, according to power or even power in the antenna, has little meaning, as a large and indefinite part of this is always wasted in the ground.

antenna, h_2 that of the receiving antenna, λ the wave-length, d the distance and R the resistance of the receiving antenna, and e the base of the natural logarithms. Here the currents are given in amperes, the distances in kilometres and the resistance in ohms. In its first form, as given after the Brant Rock tests, the formula was written

$$(2) \qquad I_R = 4.25 \frac{I_s \, h_s \, h_R}{\lambda \, d} e^{-\frac{0.0015 \, d}{\sqrt{\lambda}}}$$

where h stood for the full antenna height and a constant receiving resistance of 25 ohms was assumed. If the lengths in equation 1 are to be expressed in metres, it becomes

$$(3) \qquad I_R = 120\pi \frac{I_s \, h_1 \, h_2}{\lambda \, d \, R} e^{-\frac{0.000047 \, d}{1 \sqrt{\lambda}}}$$

and if instead of the received current, we wish to represent the electric field intensity at the receiving station, produced by the sending station, we may write

$$(4) \qquad E = 120\,\pi \frac{I_s \, h_1}{\lambda \, d} e^{-\frac{0.000047 \, d}{1 \sqrt{\lambda}}} \text{ Volts per metre.}$$

expressed in metres and amperes. Then the total E.M.F. on the receiving antenna would be E.h. Aside from the exponential term, equations 1, 3 and 4 are derived directly from the equations of the Hertzian oscillator, where h_1, the effective height, represents the length of one-half of the oscillator, the other half being replaced by the earth. The exponential term is empirical and takes account of the absorption of the waves in passing over the earth's surface, of the escape of energy into the upper atmosphere, and its partial reflection and refraction in the upper atmospheric layers. The constant of this term as given applies only to daylight transmission over salt water; for transmission over land the constant would have to be varied according to the nature of the country lying between the stations; while for night transmission, especially at the shorter wave-lengths the equation can perhaps not be applied at all. Even for day transmission and over salt water the formula represents only average results.

The variations in the absorption, reflection and refraction in the upper atmosphere lead to great irregularities in the intensity of the wave at the receiving station. It is known that for an

indefinite distance above 100 km. the atmosphere is permanently
ionized so as to have a high degree of conductivity. Near the
earth it is a good insulator, while in the region between the
permanently ionized and the permanently insulating layers there
are various degrees of ionization depending on the sun's rays and
perhaps on direct discharges of electrons from the sun. So
perhaps we may assume that the lines of electric force constituting

FIG. 3.
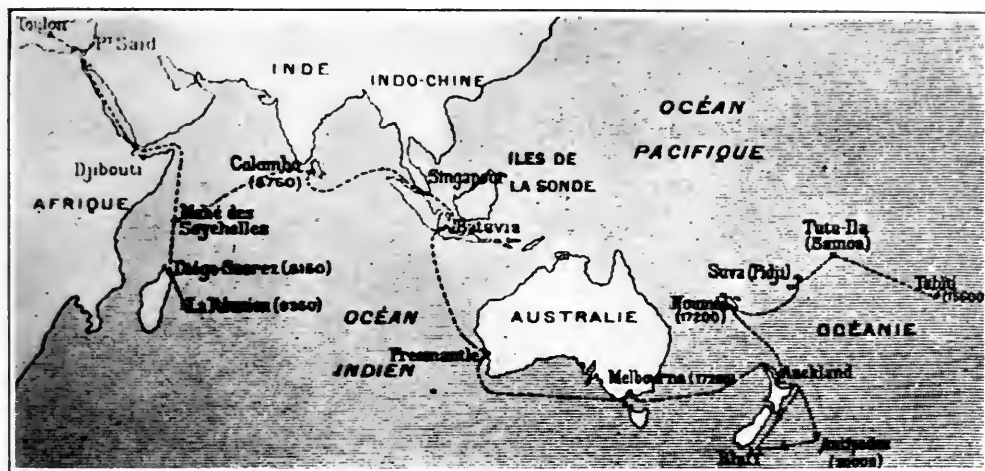
Route followed by the *Aldebaran*. The figures give the distances in kilometres from Nantes.

the radio waves are bounded below by the conducting surface of
the earth, and above by the surface of the permanently ionized
atmospheric region, while in the daytime at least there is consider-
able absorption in the region lying between. At night it is sup-
posed that the lower surface of the ionized layer is fairly sharp,
thus producing good reflecting conditions, and in this way giving
the increase in night signal intensity generally observed. Over
land where there is large earth absorption especially for short
waves, the energy of these waves may perhaps travel almost
entirely along the lower surface of the upper conducting region,
thus giving rise to the tremendous signals often observed at short
wave-lengths. It will easily be understood that the effects of all
these varying conditions, the different degrees of definiteness of
surface of the permanently ionized layer, various tilts to this sur-
face, and the various degrees of ionization in the region below
it will give rise to great variations in the quality of the transmis-
sion. These effects are most pronounced with the shorter waves
and it may be stated roughly that, for a given distance, the

variability of the signal increases nearly in inverse proportion to the wave-length. For waves of 100 m. or 200 m. the variability is noticeable at a few kilometres, while even with waves of 10,000 m. or more very large variations are sometimes observed in the communication between America and Europe.

Since 1914 several thousand observations have been made at our laboratory in Washington on the strength of signals from the high-power European stations, especially Nauen, Germany, (6600 km.) and the average of the observed values agrees fairly

TABLE I.

Comparison of Atmospheric Disturbances, San Francisco and Washington.

SAN FRANCISCO OBSERVATIONS.

Date and time.	Direction of static.
Aug. 11: 3 P. M.	E.
Aug. 12: 10 A. M.	E.
Aug. 13: 2 P. M.	4° S. of E.
Aug. 14: 3 P. M.	E.
Aug. 16: 10 A. M.	E.
Aug. 16: 3:30 P. M.	4° S. of E.
Aug. 17: 5 P. M.	5° S. of E.
Aug. 18: 4 P. M.	9° S. of E.
Aug. 19: 3 P. M.	9° S. of E.
Aug. 20: 2 P. M.	10° S. of E.
Aug. 21: 3 P. M.	8° S. of E.
Aug. 23: 4 P. M.	2° S. of E.
Aug. 24: 1 P. M.	4° S. of E.
Aug. 25: 3 P. M.	8° S. of E.
Aug. 29: 6:30 P. M.	8° S. of E.
Aug. 30: 2 P. M.	8° S. of E.
Aug. 31: 4 P. M.	3° S. of E.

Estimated accuracy 2°-4°

WASHINGTON OBSERVATIONS.

Direction.	Number of times observed.
W.	1
W. by S.	5
W. S. W.	25
S. W. by W.	22
S. W.	11
S. W. by S.	6
S.	4

Estimated accuracy 3°-10°

well with the calculated values, so at present we feel sure of the approximate accuracy of the formula up to 6000 or 7000 km. But it must be remembered that the formula represents only average daylight values, and that the observations on individual days can be more than ten times either greater or less than the average, while temporary local absorption may in certain places for a period of a few hours reduce the signal to 1 per cent. or less of its normal value. This variability, even at the long wave-lengths, together with the atmospheric disturbances, constitutes the chief difficulty which at present makes absolutely continuous trans-Atlantic communication impossible. In addition to the regular observations at Washington, the Navy has also carried on many

transmission measurements at other points, extending over limited periods of time. Some of the results are shown in Table II.

The examples in this table have been chosen so as to show not only the general agreement between the observed and calculated values, but also certain exceptions. For instance, it has long been thought that the reception in San Diego from Pearl Harbor (Honolulu) is poorer than that at San Francisco, and the measurements of the receiving field at the two places support the general impressions of the operators, the observed values at San Francisco being even somewhat better than the calculated, while

TABLE II.

Electric Field Intensity in Microvolts per Metre.

	Obs.	Cal.	Dist. Km.	
Pearl Harbor received				
at San Diego...............	12.1	33	4050	July, August,
at San Francisco	55.4	37	3900	Sept., 1920
Reception in Porto Rico from...				
Annapolis.................	192	85	2500	
Sayville..................	64	62	2560	Feb., March,
Darien....................	115	126	1800	April, 1920
Nauen, Germany...........	8.5	7.5	7620	
Reception at Otter Cliffs from				
Nauen....................	21.6	23	5700	July, Aug., 1919
San Diego................	10	18.5	4450 (overland)	
Reception in Washington from				
Bordeaux (Lafayette).......	46.7	31.1	6160	Aug., Sept., 1919
Nauen, Germany...........	10.1	12.9	6650	
Lyons, France.............	3.8	6	6460	
Cayey, P. R...............	14	83	2590	June to Dec., 1920
Cavite received				
in San Francisco...........		0.60	11300	

those at San Diego are very much worse. Again, the field of Annapolis in Porto Rico is observed to be more than twice its calculated value, while the observations on Sayville, which lies nearly in the same direction and at the same distance, give almost exact agreement. This unexpectedly strong radiation from Annapolis towards the south has also been noticed and commented upon by observers in Buenos Aires. From European observations it is not thought that Annapolis radiates with abnormal strength in that direction, and it may be that Chesapeake Bay, extending to the southward, acts as a guiding conductor so that the waves are strengthened in a southerly direction.

The very low strength of field observed in Washington from Cayey, Porto Rico, only 17 per cent. of the calculated value, shows the unfortunate effects of an unfavorable situation of a transmitting station. Cayey is situated in the interior of Porto Rico and

FIG. 4
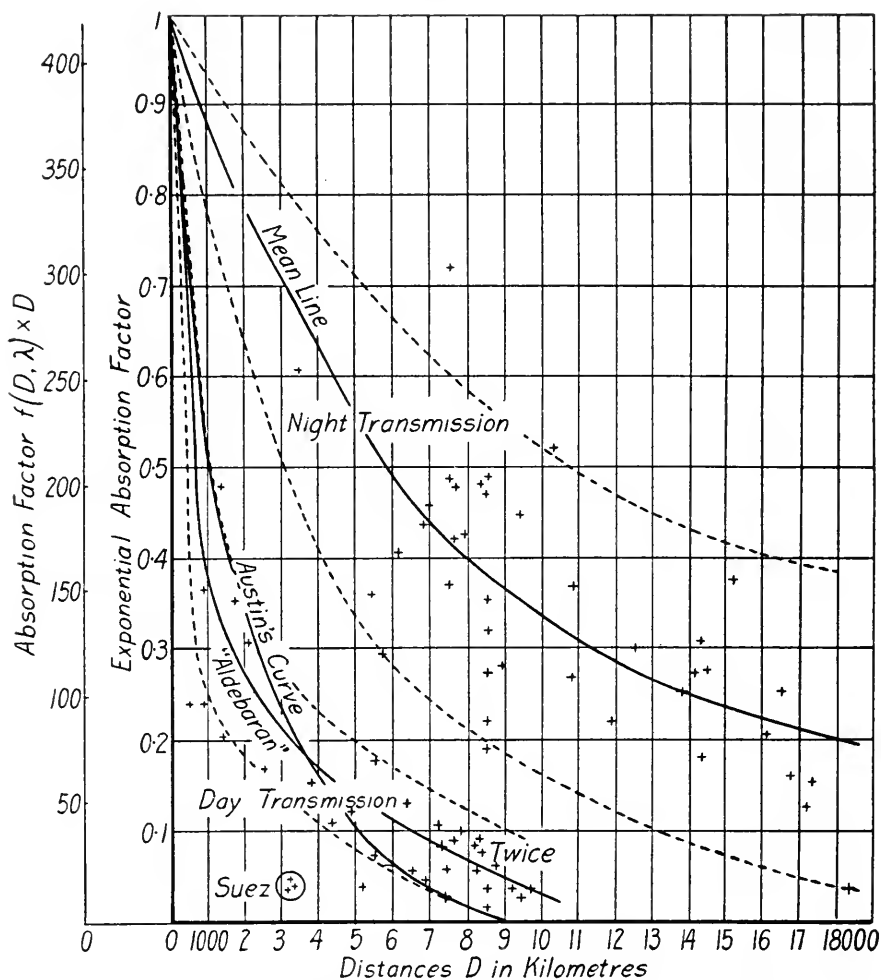
Curves for transmissions from Nantes on 9000 metres absorption factors (reduced to 1000 km.) as functions of the distance.

is almost surrounded by ranges of hills higher than the antenna which undoubtedly absorb and deflect the waves.

In 1920 the French cruiser *Aldebaran* made a voyage through the Mediterranean, Red Sea and Indian Ocean to the island of Reunion lying east of Madagascar, and then sailed eastward by way of Singapore to Australia and Tahiti. During the whole voyage, measurements were made on the strength of the signals from the French arc stations at Lyons and Nantes, measurements

in the daytime being successfully made as far as Reunion, and at night all the way to Tahiti. Aside from the large amount of radio data on the variability of signal and the differences between day and night reception at extremely great distances, a very curious deduction can be drawn from the observations in the Red Sea and in the Indian Ocean. The observed intensities follow our calculated values fairly closely as far as the Suez Canal, but after the ship entered the Red Sea it is seen that the daylight observed curves lie very much above the calculated,

FIG. 5.
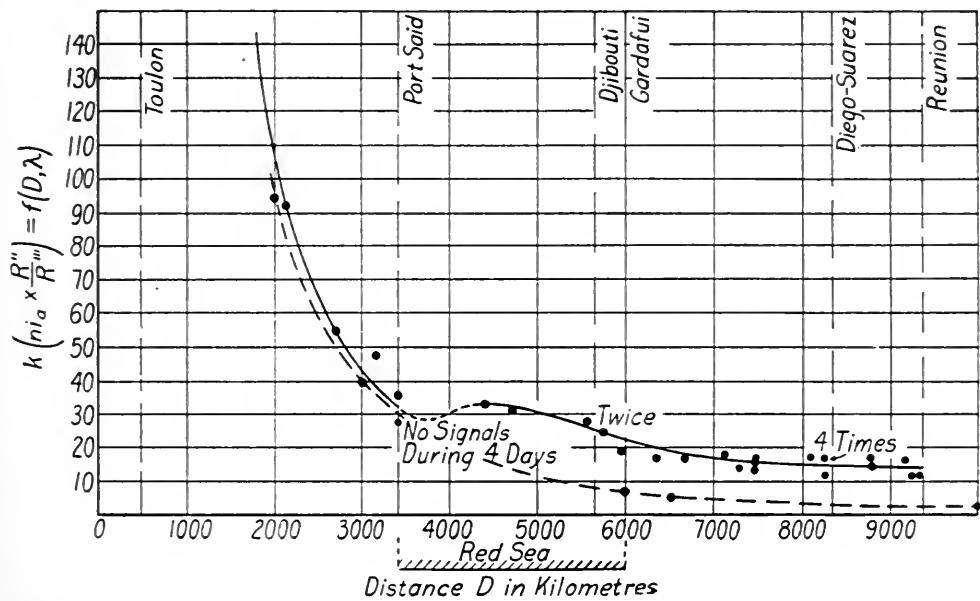
Received signal strengths between Toulon and Reunion. Transmission from Lyons on 15,000 metres.

in fact the Lyons curve (wave-length of 15,000 m.) makes an actual upward bend, as shown in Fig. 5. These high observed values continue throughout the Red Sea and also in the Indian Ocean. These discrepancies led the French engineers to the conclusion that the transmission formula was not to be trusted for distances much beyond 4000 km. I believe, however, that the true explanation is the following: The Red Sea is an elongated body of salt water lying between two extensive desert regions across which the radio waves are able to move only with great energy loss. This condition of things leads to a concentration of intensity in the better conducting region of the sea, which guides the waves from the Mediterranean through to the Indian Ocean, where they again spread out as though coming from a new source.

From this standpoint it would be of the greatest interest to carry on experiments on the apparent direction of Lyons at various points in the Indian Ocean. This tendency of water to guide radio waves is well known at short wave-lengths, and especially in aircraft radio where a strengthening of signal is almost always observed when the airplane approaches a river extending in the direction of the sending station.

There are at present a number of plans for radio communication over distances much greater than those regularly covered

TABLE III.

Contemplated Communications.

	Nautical Miles	Km.
Paris to		
Saigon...................	5500	10200
Buenos Aires..............	5950	11000
Holland to		
Java....................	6100	11300
Berlin to		
Buenos Aires..............	6400	11850
San Francisco to		
Shanghai................	5300	9800
New York to		
Buenos Aires..............	4500	8350
Leafield (Eng.) to		
Capetown via Egypt........	5300	9800
	In approximately 2000 mile steps	
Leafield to		
Australia via Egypt, India and Singapore............	7700	14200
	In approximately 2000 mile steps	

up to the present time. The Federal Radio Telegraph Company, of San Francisco, is planning the erection of two huge arc stations at San Francisco and Shanghai, a distance of 5300 nautical miles. The towers of the new stations are to be 1000 feet in height with arcs of 1000 KW. giving antenna currents of 600 amperes or more, and with probably a wave-length of between 20,000 and 30,000 m. The problem of regular communication at such a distance is very difficult, at least in regard to the reception at Shanghai. As has already been said, San Francisco offers remarkable facilities for receiving on account of the peculiar directivity of the atmospheric disturbances which permits them to be practically eliminated in reception from the

west by unidirectional receiving apparatus. According to the
transmission formula, for distances beyond 2000 miles, in order
to keep up a given strength of received signal, the antenna current
must be nearly doubled, that is, the power must be quadrupled
approximately for every additional 700 miles of distance. The
antenna current for continuous communication to Shanghai must
then be, if the formula is correct at this distance, about twenty-one
times that required for continuous communication from San
Francisco to Honolulu, since the distance is 3200 miles greater.

FIG. 6.
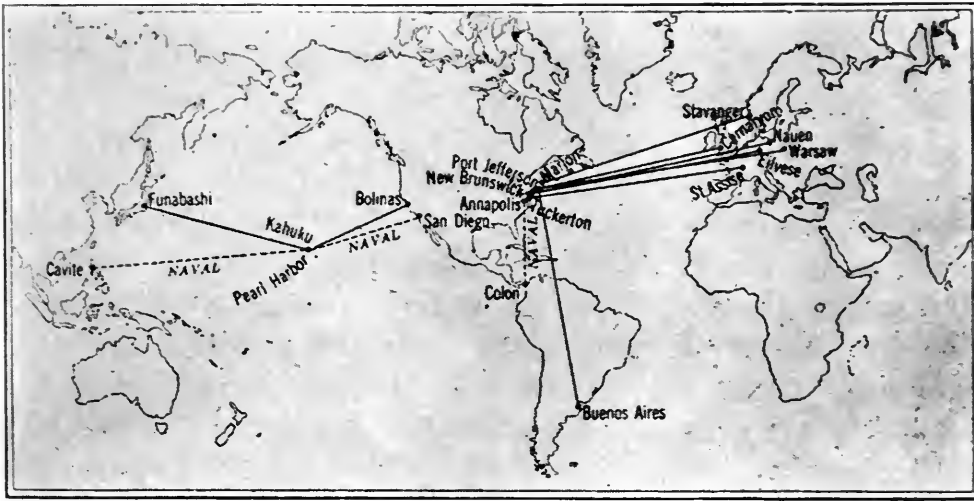
American radio plans.

In addition to the decrease in average strength of signal with
the distance, a great increase in variability of signal must
be expected.

Another project for extremely long distance radio communi-
cation has been undertaken by the Radio Corporation of America
for connecting New York with the Argentine, a distance of 4500
miles. The recently opened Radio Corporation station near Port
Jefferson, Long Island, will form the New York terminal for
this service, and will also communicate with points in Europe.
This station when fully completed will probably be the most
powerful in the world. It will be in reality twelve stations in one.
The twelve antennas radiating from the central power house like
spokes of a wheel are each suspended on six towers 410 feet high,
carrying spreaders 150 feet long for the support of the 16 wires
of the antenna. The distance between the towers is 1250 feet,

making each of the antennas about 1.5 miles long, and the total area covered by the system nearly 10 square miles.[3] It is stated that there will be ten 200-KW. Alexanderson high-frequency alternators to supply the antenna currents. It is planned to use the different antennas for separate services when transmitting conditions are favorable, but when required all can be thrown in parallel so that the power of 2000 KW. and an antenna current of 2000 or 3000 amperes will be available. At present two of the antenna units with their two alternators are in service. It will be noted that the towers are not as high as those of most of the great stations of the world, while the contemplated antenna currents are larger. It is a theory of Mr. Alexanderson that by means of his special multiple ground system, already mentioned under the discussion of ground resistance, antenna current can be increased more economically than the height of the towers. Theoretically, as has been mentioned, the field produced by the station is proportional to the product of the antenna current times the height. This station may be said to represent an extreme effort to conquer the difficulties of radio communication by power. But it remains to be seen whether even this enormous power will give constant communication with Buenos Aires, for here the conditions are even less favorable than those for the San Francisco-Shanghai circuit, since the path of the waves will lie largely over land and the direction of the atmospheric disturbances will at both ends of the circuit be unfavorable for unidirectional disturbance elimination. The receiving conditions in Buenos Aires have not in general been found very satisfactory by parties of foreign engineers who have carried on investigations there. Recently, representatives of the German Telefunken Company have reported much better receiving conditions around Rio Janeiro, and the newspapers have lately announced that the Radio Corporation of America is contemplating a station at this point.

In England plans have been made for bringing the various parts of the British Empire into radio connection. Unlike the plans for communication over vast distances by means of huge stations, the Imperial committee, headed by Sir Henry Norman,

---

[3] Before the close of the war the U. S. Navy had designed an enormous station with a radiating antenna system in which the antenna could be used singly or in parallel, and which was to have been erected in the south. The coming of peace prevented the carrying out of this plan.

has recommended that stations of only moderate power be used, spaced at distances of not more than 2000 nautical miles, the intermediate stations acting as relays for the more distant. The first station of the Imperial chain, Leafield, near Oxford, was opened last summer and is expected to communicate with a station about to be built near Cairo. From Cairo the Imperial chain divides, one line extending to South Africa with an intermediate station in East Africa, while the other is expected to reach Australia by way of India and Singapore. According to the original recommendations, the stations of the Imperial chain

Fig. 7.
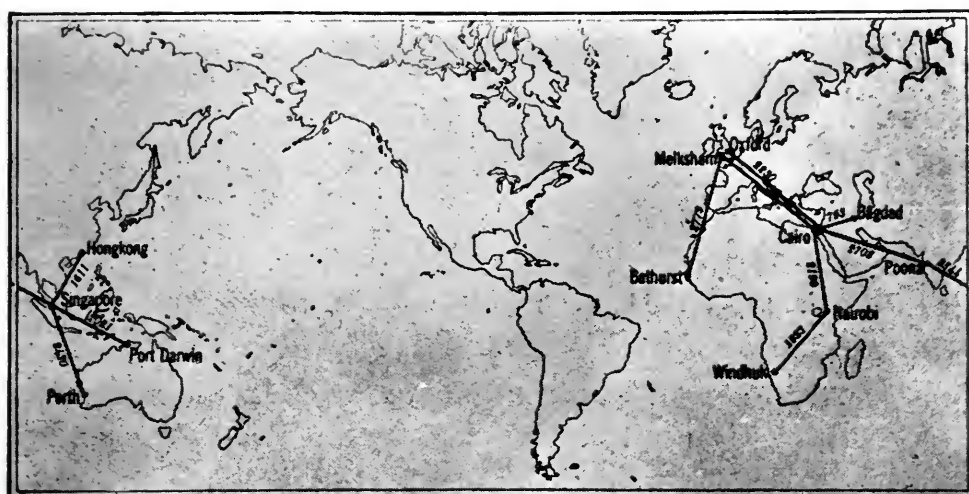
British Imperial scheme of 1919 for radio communication.

were to be equipped with electron tube generators, but apparently the British Post Office does not feel that the tube generators have been developed to the point where this is advisable. Therefore the station at Leafield has been furnished with a 300-KW. arc giving a current of about 250 amperes in the antenna. At present the masts at Leafield are only 300 feet high, having been installed there by the Marconi Company before the war. Later it is expected that these will be replaced by 600 or 800 feet masts. There have been heated discussions in England regarding the relative merits of the high-power, long-distance transmission systems in comparison with the moderate power, intermediate relay systems. There can be no doubt that the system of intermediate stations will give by far the most reliable communication, largely on account of the smaller variability of signal intensity at shorter

distances. And probably for Government purposes where reliability is of more importance than volume of traffic carried, this system is superior.

The plans of France for extremely long distance communication are centered around the huge transmitting station now being completed at Sainte Assise, between Fontainbleau and Paris. This station is expected by its promoters to communicate with Saigon, Indo China, 5500 nautical miles, Buenos Aires, 5950 miles, and of course many nearer points. The antenna for the high-power service is of the double Marconi type, being constructed in two parts with independent down leads in the centre. It is supported on sixteen 250-m. towers in two rows, 400 m. apart. High-frequency current will be supplied by two 500-KW. Latour alternators which will be used separately on the two antennas or which, when required, can be placed in parallel with the two antennas used as one, thus supplying 1000 KW. which will probably give between 1000 and 2000 antenna amperes. In addition to the high-power station, there is a medium power station for communication with European points, having a single mast 250 m. high which supports four antennas, which can be used independently or as one unit. High-frequency current is supplied from four 25-KW. alternators. There is also a low-power tube generator station with a 100-m. mast for communication with London and other nearby points. The receiving station for Sainte Assise is at Villecresnes, where there are six two-story brick buildings, the second stories of which contain the receiving coil antennas while the other receiving apparatus is on the ground floor.

At present France possesses in the Lafayette station near Bordeaux the most powerful station in the world, though it will soon be surpassed by both Sainte Assise and Radio Central on Long Island. Lafayette is an arc station built near the close of the war by the American Navy. It has a Marconi type antenna supported by eight American Navy type self-supporting towers 250 m. high. High-frequency current is supplied by a 1000-KW. Federal arc giving a maximum current of 600 amperes at about 24,000 m. wave-length. This gives at present approximately twice as strong an electric field in America as any other European station.

The second most powerful station now in operation is the

German alternator station at Nauen, which is the veteran among
high-power alternator stations, having been in continuous use
since 1914. The antenna is supported by two 250-m. towers in
the centre, with lower towers supporting the antenna ends. There
are two 500-KW. generators, and the normal antenna current
is 380 amperes. The receiving station associated with Nauen
is at Geltow, near Potsdam.

Holland has under construction two stations for communi-
cation between the home country and Java, a distance of 6100
nautical miles, almost entirely over land. The home station, near

FIG. 8.
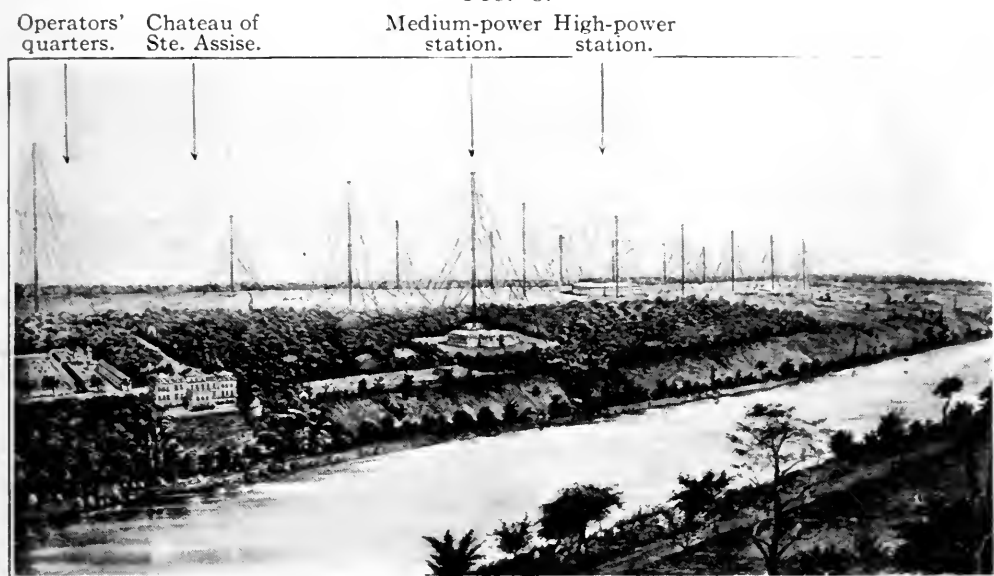
General view of the Ste. Assise station.

Amersfoort, is reported to be of the same power as Nauen. The
Java station in the Malabar mountains is of interest on account
of its novel antenna construction. The antenna is suspended
between cables stretched across a gorge 3000 feet deep. One
would not naturally expect that an antenna hemmed in between
mountain walls would be very efficient, but it is claimed that
experiments recently made have conclusively shown it to be
entirely satisfactory. It was used in some interesting experi-
ments during the war in the attempt to establish communication
with Holland independent of the cables. In these experiments
it was found that during a considerable portion of the time it
was possible to send messages to Holland at night even with
quite moderate powers, provided wave-lengths of 5000 or 6000 m.

were used. Of course such short waves would not be heard at all at this distance in the daytime.

Now as to the future of long-distance radio; it was stated in the beginning of the paper that the distances which can be covered in radiotelegraphy have always been limited by the receiving apparatus, and I see no reason to believe that this will not continue to be true in the future. At present there is a tendency to attempt to solve the problem of transmission by

Fig. 9.
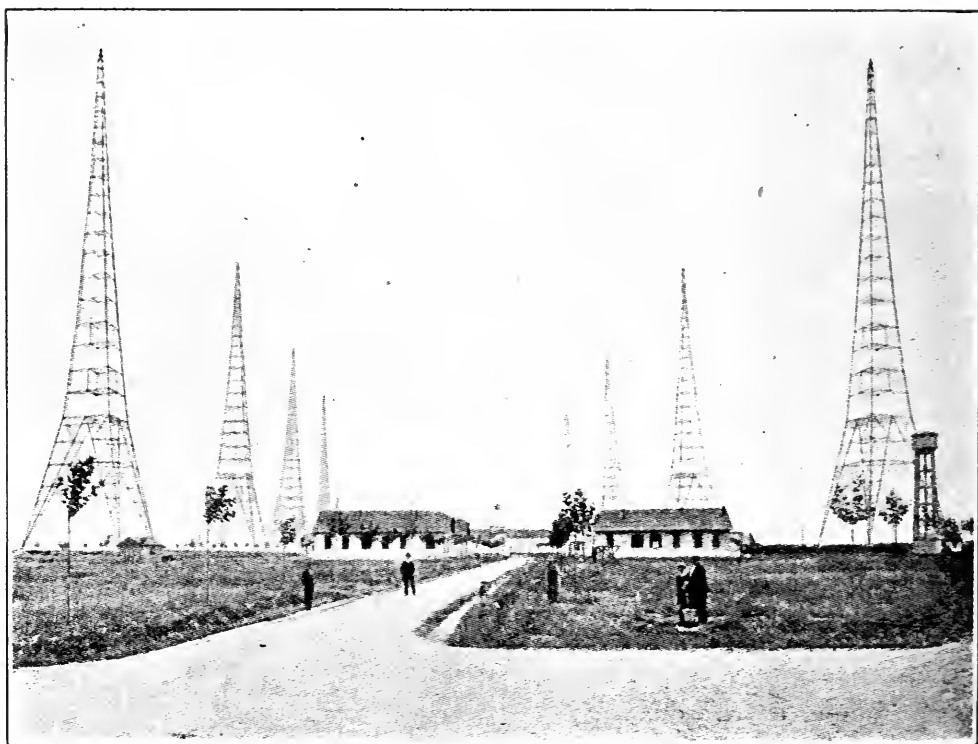
View of Lafayette station near Bordeaux.

the use of enormous power, and it is possible that this can be done for covering distances of 3000 or even 4000 miles. But when one considers the power costs involved and the expense of erecting and caring for the enormous antenna structures which will be required, there is evidently a limit beyond which it is not profitable to go. This is the more evident when one remembers that doubling the antenna current, that is, quadrupling the power, can only double the telephone current in the receiving station, or in other words, only double the signal disturbance ratio which is

In the January 12, 1922, issue of *Nature* there is an interesting discussion between two eminent chemists, one German, the other British, on the introduction of "Chemical Warfare." Sir T. E. Thorpe, in reviewing Lefebure's book "The Riddle of the Rhine," cited a passage, which, Geheimrat F. Haber claims, had "the intention to make the world believe that the materials for gas warfare were prepared by the German military authorities and chemical industry for the intended war and that experiments with this end were carried out in my institution (*i.e.*, Kaiser Wilhelm Institut, Berlin), if not previous to the war, at least from August, 1914, onwards." Such preparation Professor Haber denies categorically in these words: " Yet among all these men I have never met one who, previous to the war or during the first two months of its course, had conceived the idea of providing the field army with gas, or had made experiments or preparations for such a purpose. We had actually first to read in the French, Italian, and English press—as, for instance, in the *Pall Mall Gazette* of September 17, 1914—of the terrible things that were in preparation for us before we began to make similar preparations in view of the commencement of the war of position. . . . The question of gas as a means of warfare did not begin to engage our attention until the first three months of war had passed." The most significant statement of the German scientist is this made in discussing pre-war plans for gas warfare: " Perhaps there might have been some ground for suspicion if Germany could have foreseen the trench warfare, and if we could have imagined that the German troops could ever be held up for weeks and months before the enemy's wire entanglements." This frank avowal that Germany might have discarded her obligations to the Hague Convention before the outbreak of the war with the same conscienceless readiness with which she converted Prussia's guarantee of the neutrality of Belgium into the notorious " scrap of paper," this makes even more knotty the problem that many former residents in Germany are trying to solve, that is, how to reconcile the personal morality of the German citizen toward his fellows with his aggressive immorality in international relations.

In his reply Sir Edward Thorpe refers to this, that in 1887 the great organic chemist, Baeyer, in Munich, called attention in his lectures to the possible use in war of certain compounds causing temporary blindness. " The implication that the Allies were contemplating the use of poison gas as early as September, 1914, is so notoriously at variance with the truth that it scarcely needs serious refutation. If Geheimrat Haber could only have been present when Lord Kitchener made his dignified protest in the House of Lords, or have been a personal witness of the wave of indignation and disgust that swept over the country at the Germans' breach of the rules of war, he would not have penned his statement." " After all, the essential point is that it was used, and first used, by the Germans, and in flagrant contravention of a solemn promise given to the world."

G. F. S.

SURVEYING FROM THE AIR.*

BY

COLONEL E. LESTER JONES, A.M.

Director, U.S. Coast and Geodetic Survey; Commissioner, International Boundary—
United States—Alaska and Canada.

ONE HUNDRED AND SIX years ago the United States Coast Survey, which later became the Coast and Geodetic Survey, began the task of charting the coastal areas of the United States. This task now includes all the outlying possessions since acquired, sections of which have not, as yet, been adequately surveyed. Portions of the coast, especially the Atlantic Coast, have been repeatedly surveyed, necessitated by the constant changes continually occurring. The action of waves, currents, tides, wind and man produces changes which render charts obsolete in a few years. It is in the accurate and detailed recording of these changed areas that aerial surveying will find its most useful application to the work of the Coast and Geodetic Survey.

The surveying done by the Bureau differs to a greater or less degree from surveying carried on by other organizations in this country, and this has necessitated the development of special methods and equipment to suit our particular needs. The standard methods and equipment of to-day are the result of successive improvements during the history of the Bureau, and to a large extent are due to the efforts of the personnel of the Bureau. Some methods and instruments have grown entirely within the Bureau, while others are adaptations of developments in other lines of scientific endeavor. A study is made of all inventions, discoveries and improvements that give promise of usefulness in surveying. Thus it was that the development of aerial photography was a subject of interest to members of the Coast and Geodetic Survey before the World War, an interest that was intensified by the rapid strides made in aeronautics during the war. As soon as possible following the Armistice arrangements were made with the Air Services of the Army and Navy to carry on coöperative experiments in aerial mapping, with the result that in June of

---

* Presented at a meeting of the Section of Physics and Chemistry of The Franklin Institute held Thursday, March 2, 1922.

1919 the Army Air Service photographed Atlantic City from the air, while during the following month the Navy Air Service experimented in the photography of underwater features in the vicinity of Key West, Florida.

In March of 1920, the Army Air Service photographed almost the whole outer coast line of the State of New Jersey for the Coast and Geodetic Survey. The Navy Air Service did some mapping of the Delta of the Mississippi River for the Coast and Geodetic Survey in March of 1921, and resumed operations there in the fall of the same year.

The various projects surveyed by the two Air Services have demonstrated the advantages of aerial photography for revision work for charts. There is one point especially in favor of this new method that should be stressed above all others, as it is the watchword of government organizations at the present time, and that is—economy. An aerial survey along the coast costs about one-third as much as a ground survey of the same region, and for this reason, if for no other, arrangements should be made for an extensive aerial mapping program.

We are planning to resurvey all of the changeable coast line of the Atlantic and the Gulf with the help of the Army and Navy Air Services, and the work will be done as rapidly as the funds and personnel available will permit.

The necessity for correct charts is obvious, and here is the chance to publish up-to-date charts at a small outlay for field work and, at the same time, furnish a peace-time vocation to the Air Services.

SURVEYING ACTIVITIES OF THE COAST AND GEODETIC SURVEY.

Before describing the experiments in aerial surveying in which the Coast and Geodetic Survey has taken part, it would be well to touch on some of the activities of the Survey, especially those with which aerial surveying is allied. Some of the ground methods now in use may eventually be replaced, either wholly or in part, by the aerial method, but at present practical aerial surveying is limited to only one phase of survey work, and that is the delineation of topographic features. The field of usefulness may be extended to other branches of surveying after much experimental work has been done, including improvement of instruments and perfection of methods.

Geodesy.—The basis of every extensive survey, and this includes aerial surveys, is a scheme of triangulation. The geodetic work of the Bureau includes among its operations three forms of triangulation, precise, primary, and secondary, the purpose of which is to furnish adequate control points for other surveys. A scheme of triangulation consists of a network of triangles, the vertices of which are known as triangulation stations, which are generally elevated above the surrounding country so as to be intervisible. These stations may be on hills, ridges, or mountain peaks, on lofty structures, as lighthouses or towers, or on level ground where special structures are erected to make the stations intervisible. The instrumental observations consist of the measurement of the angles of the triangles by means of a theodolite set up at the stations. The distances between stations are determined by computations.

Other geodetic operations bearing a close relation to triangulation are the astronomic observations for latitude and longitude, and the measurement of bases. The astronomic observations are made at stations where they can be tied in with the triangulation. Base measurement consists of the actual measurement along the ground of one side of a triangle in the scheme of triangulation. This measured line is used as a base for computing the sides of the triangles.

At present accurate aerial mapping requires numerous triangulation stations as control points where the area has not been previously surveyed. It is probable that aerial mapping may be so improved in the not distant future that fewer triangulation stations will be needed.

Topography.—The topographic surveying of the Coast and Geodetic Survey is limited to the areas bordering the coasts of the United States and its possessions. A topographic party, generally consisting of one engineer and four or five men, usually works as a sub-party attached to a vessel of the Survey, and it uses a launch or rowboat for transportation. The standard equipment is the plane table which has been in use many years and is well known. A large sheet of drawing paper is stretched over the board of the plane table, and on this sheet the engineer indicates in their true geographic position the shore line at high and low tide, marshes, woods, houses, villages, streets, wharves, bridges, railroads and any other features needed on the chart.

The topographic work along the Atlantic Coast at the present time consists only of revision of the older surveys. By ground methods this is almost as laborious a task as making a complete new survey, as often the changes are so numerous that the chart based on the old survey is hardly recognizable. It is in this revision work that aerial surveying has demonstrated its importance. A direct comparison between the photographs and the older survey can be made, and the changes that have occurred during the elapsed time can be easily discovered. In nearly every case there will be so many unchanged objects on the old map included in the photograph that the changes can be fitted into the old map without having to establish any control stations by ground surveys.

The aerial photograph contains much more data than the plane table sheet. The minute detail shown in the photographs can only be equalled by the topographer after a laborious and costly survey. Every bend shows in even the smallest streams. To one experienced in the interpretation of aerial photographs almost all the features ordinarily sketched in by the topographer can be recognized in the photographs.

It can be readily seen that the aerial photograph is especially valuable where there is a great amount of detail such as is found in a marshy area and in a village.

Along the coast of Florida there are many miles of coast line where the forest growth extends out into the water, and it is necessary for the topographer, using the old methods, to carry on most of his work while standing in two or three feet of water. Often the water is so deep that he cannot set up his instrument, and the work has to be done with a boat and sextant. This is a very unsatisfactory method and the aerial survey seems to be the logical one to be employed along coasts similar to this.

Many of the bays of the South Atlantic and Gulf coasts are bordered by marshy land, quite often too soft to hold a plane table with the requisite rigidity. These marshy areas are usually covered with a network of small streams that twist and wind their way through the soft soil. The accurate survey of these numerous streams by ground methods is a slow and costly process.

Hydrography.—Hydrographic surveying, or the delineation of under-water features with the lead line, has always been a more or less uncertain process, a groping in the dark. Sounding is car-

ried on from boats varying in size from a rowboat to the largest surveying vessel, the size used depending upon local conditions. A whaleboat or small launch is used for work close to shore, or in shallow bays, while large launches or vessels are used in the exposed areas. Soundings with the lead are taken at intervals of 100 feet or less in harbors, while in less important or deeper waters the interval is greater. Location of the soundings is determined by means of sextant observations from the boat made on signals on shore. A record of every observation and sounding is made and the soundings are plotted on a large sheet of paper in their correct positions.

An inspection of a hydrographic sheet gives one the impression that additional surroundings are hardly necessary, that the territory is well covered, but even the most detailed surveys are insufficient in some localities. Dangerous pinnacle rocks have been missed by the sounding lead.

To eliminate the uncertainties of the lead line survey the wire drag was perfected. A wire towed by launches sweeps through the water at a specified depth, say 80 feet. Any obstruction projecting above the 80-foot depth will catch and hold the wire, and can then be located and examined closely. The drag gives very certain results, as all objects projecting above the level of the wire can be charted.

The possibilities of aerial photography as an aid in charting under-water features was investigated by the Coast and Geodetic Survey in 1919 in coöperation with the Air Service of the Navy Department, with the hope that some of the usual hydrographic work could be eliminated. It had long been known that under-water features were visible from high altitudes, especially along the southern coasts, and the possibility of photographing the ocean bottom gave promise of material assistance in hydrographic surveying. The results of the experiments made in surveying the water from a plane will be described later.

HISTORICAL NOTES ON MAPPING FROM THE AIR.

Colonel Laussedat, a French army officer, suggested the use of aerial photographs for mapping purposes as early as 1845, in connection with his general investigations on photographic surveying. Those subsequently taking part in the development of ground photographic surveying also touched lightly on the aerial

phase, but very little advance was made until the beginning of the twentieth century.

Theodor Scheimflug, an Austrian, at the time of his death in 1911, was engaged in very promising researches along the line of aerial mapping. He had perfected a multiple camera for aerial use and a transformer for the correction of negatives for obliquity. The camera was designed for use in a balloon or kite, and consisted of a central camera pointing vertically down and seven other cameras arranged about the one in the centre and pointing obliquely in directions radiating from the centre. The seven oblique photographs, after rectification in the transformer, were combined with the central photograph to produce a composite photograph of an area whose diameter was five times as great as the altitude from which the photographs were made. This camera cannot be used to advantage in an airplane, and as the airplane is superior for mapping purposes to the balloon or dirigible, the instrument is very little used at the present time. The principles involved in the design of the 8-chambered camera and the transformer have been of great assistance in the development of aerial mapping and of equipment for use in the airplane and in the laboratory. Although aerial photography was limited to kites, balloons and dirigibles before the war, the experiments proved of value in demonstrating some of the difficulties that might be expected in photography from airplanes.

The world war demonstrated the importance of airplanes and aerial photography as war-time adjuncts, and also brought into prominence their peace-time possibilities. Aerial cameras were designed in great numbers in an attempt to find an efficient one. Each nation contributed a variety of models and tried them out at the front. The designers knew that an aerial camera must necessarily be of different construction from that of a camera for ground use. It should be simple in operation and automatic if possible. It should be substantial in construction so as not to be affected by vibrations. It should not be affected by low temperatures, or low atmospheric pressures, and should be capable of producing good results under conditions generally considered to be adverse for the ordinary camera. In the United States the K-1 type camera and the Bagley camera were designed. These are the two types being used almost exclusively in mapping for our federal agencies, and they appear to be superior to any other camera so far

tried in this country. Improvements have been made in these cameras from time to time.

The problem of the stabilization of the camera received attention in the countries interested in war mapping. Various devices were tried out, but none was entirely successful. The gyroscope received a great deal of attention, and its use was believed to be the solution of the problem, but no one has brought forth a satisfactory gyroscopic stabilizer. Level bubbles on the camera were used with some degree of satisfaction during the war, and at present are the only means used in this country to ascertain the verticality of the camera.

It may be well to note here that any statement made in this paper as to the superiority of any particular appliance or method refers to those known to the Coast and Geodetic Survey. With so many governments and commercial firms experimenting in aerial mapping, all attempting to advance, improvements may have been made recently which have escaped our notice.

As aerial cameras needed better lenses than the ordinary cameras, so also was the need made evident for improvements in plate emulsions and in filters. Experiments along this line have continued since the war, and now plates and films are especially treated for aerial use. The developing of roll films 75 feet and more in length has received some attention, several different models of development machines being now in preparation for the market.

A number of European countries have experimented in aerial surveying. The British are particularly interested, the large unsurveyed territories in India and Canada being the objective. Several surveys have been made in each of those countries.

In the United States the two Air Services have made aerial surveys for their own use, and for the use of the Geological Survey, Corps of Engineers, Hydrographic Office, Forest Service, Bureau of Soils and the Coast and Geodetic Survey. A few commercial firms have done some mapping, but most of their mapping is on a small scale.

Some interesting mosaics have been constructed at various times. A very good mosaic is the one of Rochester, New York, made by the Eastman Kodak Company and the Army Air Service.

To many persons a photograph is more intelligible than a map,

and consequently there may be created a demand for mosaics that will result in quantity production.

The term mosaic, as commonly used by aerial photographers, refers to a composite photograph made by joining several different photographs together. If the photographic work has been well done, and the terrain is fairly level, the mosaic will probably be very accurate, adjoining photographs overlapping perfectly or with very little discrepancy. Even in mountainous terrain a mosaic may be constructed by juggling photographs, which will appear correct owing to good joining, but it will probably be very inaccurate as to scale and direction, and cannot be substituted for a map.

Experiments are being conducted in this and other countries in the application of the aerial photograph to surveying rugged areas. We cannot predict what degree of success will be obtained.

AERIAL MAPPING PROBLEMS.

A study of the reports of the various organizations in all countries engaged in experiments in aerial mapping indicates that the majority have met the same problems and have the same difficulties to overcome.

Personnel.—The human equation is an important one in any mapping flight, so that instruments are being perfected to lessen the work of the aviators. There are few proficient mapping pilots. To maintain an airplane at a constant altitude and to keep it on a desired course over a designated territory without too much banking and turning is a task requiring the greatest skill and much experience. It is necessary to fly at a constant altitude in order that all the photographs will be on the same scale. This is especially necessary when mosaics are to be constructed. Flying at a constant altitude and on straight courses reduces the number of tilted photographs and reduces the office work.

The accompanying diagram (Fig. 1) illustrates some of the difficulties encountered in mapping from the air which must be overcome by the skill of the flyers. In figure A, there is no cross wind and the photographs overlap each other in a satisfactory manner. In figure B the effect of " crabbing " is shown. The wind is normal to the course of the plane, resulting in the plane drifting, the successive photographs covering areas as shown. In figure C the observer has rotated the camera to compensate for the drift, so that with a cross wind the pilot heads his plane into

the wind enough to overcome the drift, with the result that the photographs overlap as in figure A.

In figure D are shown the results of lateral tilt in one photograph. This illustrates how a superficial examination of the photographs composing a series will give an idea as to the stability of the camera in a flight, especially as regards lateral tilt and, to a

FIG. 1.
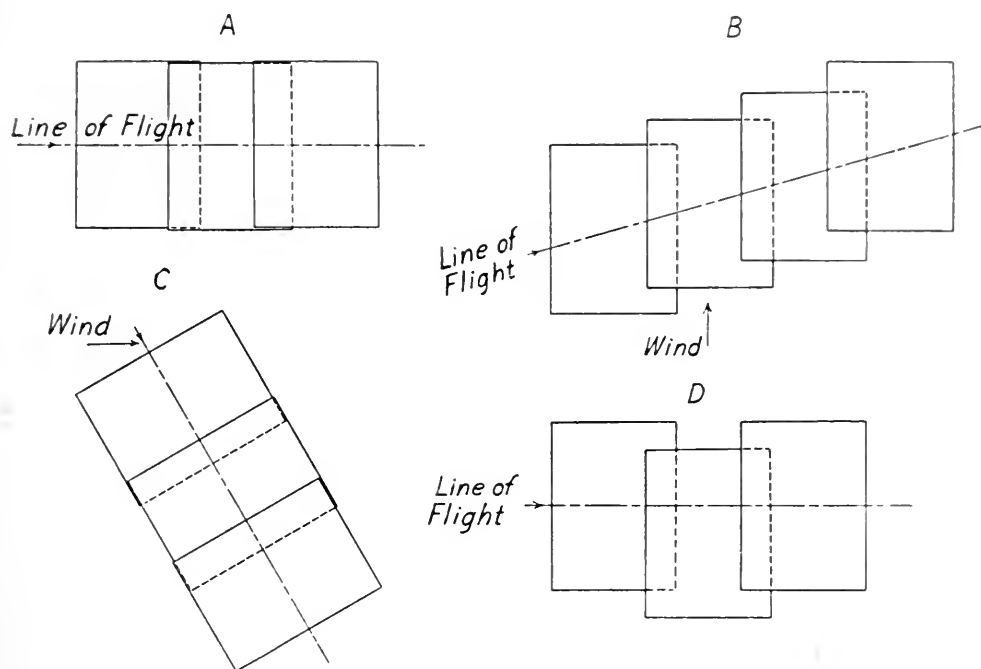
Problems for the aviator to overcome.

less extent, fore and aft tilt. A series of mapping photographs joined together should follow a straight line and have equal overlap. If any photographs are displaced from the proper position, it is an indication of tilt.

The observer's duties are being simplified by the perfection of improved cameras and will be much easier as soon as a satisfactory stabilizer can be used.

In most aerial mapping projects, an attempt is made to have the camera pointing vertically down whenever a photograph is made. If the camera is tilted from the vertical the result will be that the scale of the photograph will vary. The only method used at present for maintaining verticality is level bubbles on the camera. The observer notes the position of the bubbles just before a photograph is made and, if necessary, adjusts the camera

to the vertical position. The accuracy of the level bubble method depends upon air conditions and the ability of the aviator to maintain a steady speed and a straight course.

Limitation.—All the aerial surveying for the Coast and Geodetic Survey is at present limited to flat terrain. This is due to the additional problems involved in the office work when the photographing is done over a territory where there is much relief. Elevated objects will appear farther from the centre of the photograph than they actually are in nature. The necessary office work involved in the computation of the correct position of each of the elevated points is now excessive, but this may be overcome if some stereographic method can be developed for use in terrain of great relief.

Distortion.—Lens distortion is a problem that can be solved only by providing a perfect lens. The lenses in the mapping cameras are not now as accurate as they should be, thus causing distortions of the edges of the photographs. For each lens, distances on the photographs are accurate within a circle of a certain diameter. This circle should be large enough to include the whole photograph, but generally it is not. Outside of this circle distortion is usually quite marked and occurs on lines radiating from the centre of the photograph. The distortion varies with the distance from the centre, but is constant along each circle about the centre. If the lens has been tested and rated, allowances can be made for lens error in the compilation of results.

Although a roll film will shrink while undergoing development, the general tendency seems to be for a change to occur along lines radiating from the centre, so that the effect produced is just a slight change of scale constant throughout the film. European nations prefer glass plates to films, probably because of the non-shrinkage of plates. The advantages of films over plates, especially as regards convenience and light weight, seem to outweigh the slight errors apt to occur due to unequal shrinkage.

Distortion of photographic paper is a grave source of error as it is variable, depending on the grade of paper, the method of drying and the atmospheric conditions after drying. A thin paper is very easily distorted, so for mapping purposes a double weight paper is recommended. The handling of the paper while developing and drying is important, as any stress applied while it is wet results

in stretching the paper.   Distortion is also due to the method used in the manufacture of the paper.

It can be seen that the accumulative errors due to tilt, lens inaccuracies, and film and paper distortion might combine to produce excessive distortion in one photograph, while they might almost balance each other in the next.   With reasonable precautions having been taken to minimize the possibilities of error, the results are not as inaccurate as might be expected.

Interpretation of Photographs.—The proper interpretation of aerial photographs is a study in itself.   An oblique view is comprehensible at a glance, but a mapping photograph is a puzzle to the average person until it has been studied.   The viewpoint is so unusual that the photograph does not appear natural.   Even to the initiated, there are some features that are unintelligible.   This is no more aptly illustrated than in photographs of tidal flats along the coast.   To know what sections are above or under is a puzzle that can only be solved by a visit to the field and inspection on the ground or by means of an oblique photograph.   Oblique photographs are of inestimable value in the interpretation of mapping photographs. Doubtful detail is cleared up in a wonderful manner. But there are some conditions that are not definitely shown even in the oblique views.   Marshy land is an instance.   Rushes growing in water appear as dry land in the photographs.   This is just one illustration of the necessity for a field inspection in order to verify the interpretation of the photographic detail.

A stereoscopic study of the photographs is of great assistance in interpreting detail.   Several types of stereoscopes have been perfected for special use with aerial photographs, and a new type is under construction now at the Bureau of Standards for the Coast and Geodetic Survey.   In the meantime a Pillin stereoscope, a French instrument, is being used for studying aerial photographs.

ATLANTIC CITY PROJECT.

The first airplane mapping experiment in which the Coast and Geodetic Survey took part was the photographing of Atlantic City, New Jersey, in June and July, 1919, for the purpose of testing the possibilities of aerial photography in the revision of the topography of the coast line.   The locality was well suited for the tests as the terrain is flat, and is well sprinkled with prominent objects suitable for control points.   The marshy areas in the

vicinity are characteristic of much of the Atlantic Coast region where revision work is needed.

Various types of planes and cameras were used and tested. A

Fig. 2.

K-1 camera used for the delta work.

complete aerial survey was made with an Army plane using an L type camera. This is a plate camera, using $4'' \times 5''$ plates. It was fixed rigidly in the plane, thus making it necessary that the

pilot exercise extreme care in controlling his plane in order to keep the camera level. Every tilt of his plane tilted the camera.   An

FIG. 3.

K-1 camera used for the delta work.

Army truck with photographic trailer made headquarters at Atlantic City, and was used for laboratory work.

Prints were made and assembled into temporary mosaic form in order to see if the terrain had been completely covered.   It was

noted that the individual photographs did not join each other very well, but it was planned to rectify several of the photographs upon return to the home air station. This eventually proved to require too much laboratory work, and the compilation of results was very unsatisfactory.

Another Army plane using a K-1 camera spent three days at

Fig. 4.

Seaplane used for the survey of the delta.

Atlantic City and completed the area designated, at an altitude of 7000 feet. The K-1 type camera is entirely automatic in action and uses a roll film 75 feet long, on which can be made 90 exposures each 18 x 24 centimetres in size. A focal plane shutter is used. Motive power is supplied by either an electric or wind-driven motor. Lenses of focal lengths of 10, 12, or 20 inches are used, set at universal focus. In fact all aerial cameras have their lenses fixed at universal focus. The light weight and ease of operation are two distinct advantages of this camera. The operation of the camera being entirely automatic, the photographer is free to attend to other necessary details of mapping. Photographs are made at intervals of from 15 to 30 seconds as desired, without any manipulation by the operator other than throwing a switch to start the camera working.

Personnel of the Army Air Service constructed a mosaic, using the photographs made with the K-1 camera, that proved to be

fairly accurate. There were some discrepancies, but they were to be expected. This mosaic was the subject of much study by members of the Coast and Geodetic Survey, and the conclusion was reached that aerial photography could be advantageously used for the correction or revision of our present charts. It was decided that, while a mosaic was interesting from the pictorial stand-

FIG. 5.
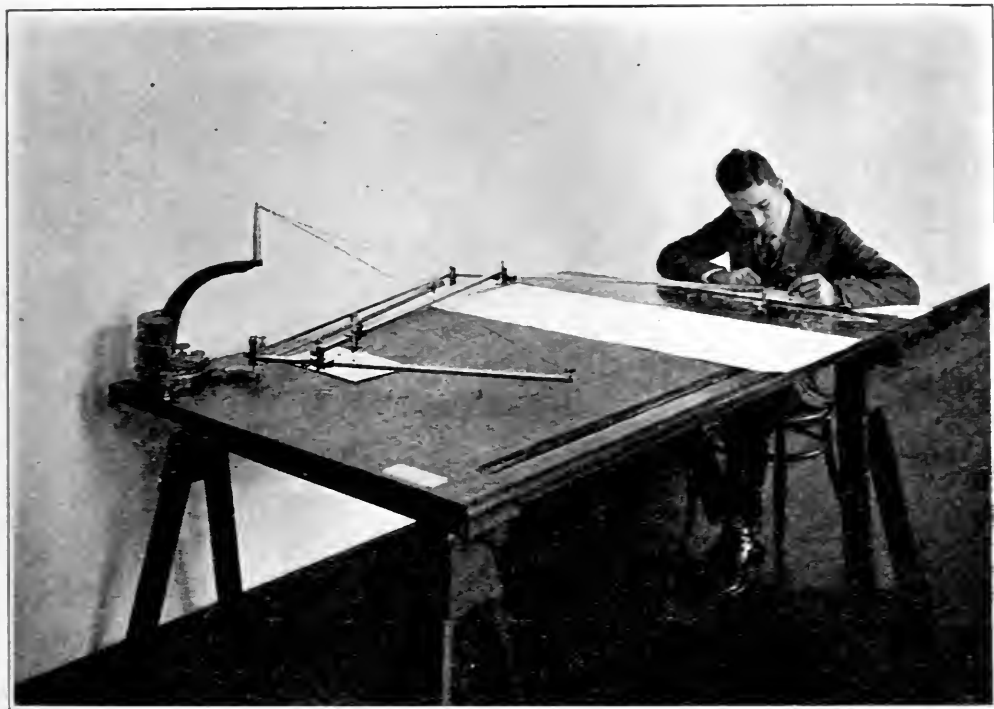
Pantograph used for reducing data from the mosaic to the scale of the chart.

point, the individual photographs were of greater value to the cartographer.

An attempt was made to map the locality from a naval plane, an L type camera being used at first, but a Bagley tri-lens camera was later used. The photographs made showed too much tilt. The Bagley camera was also used in a Navy dirigible with good results, the photographs being used to supply data in areas not covered by the K-1 camera.

The Bagley camera is a modification of the Scheimflug camera, but has only three lenses, as this number is better suited to airplane use. One lens photographs the terrain directly below while the other two lenses photograph the area on either side. The two side

photographs, being oblique, must be rectified in a transformer. After rectification, they can be joined to the central photograph forming a continuous strip covering a width approximately three times as great as the altitude from which the exposures were made. The camera is not automatic in its action.

A representative of the Coast and Geodetic Survey kept in

Fig. 6.
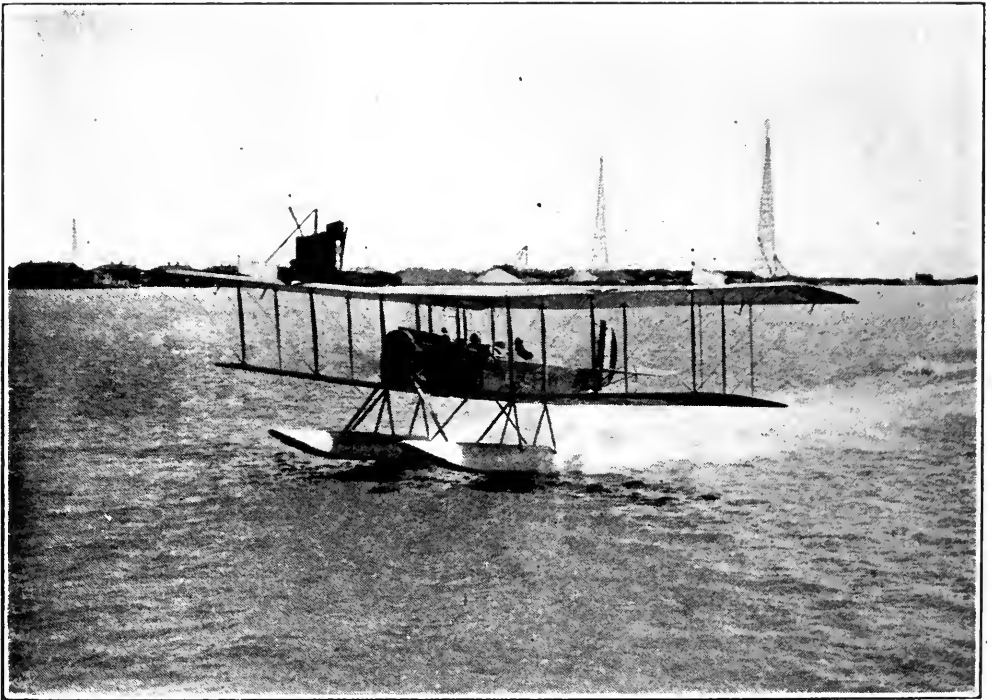
Seaplane used for the survey of the delta.

close touch with the photographic parties, and constructed some special signals for control points that would show in the photographs. These and many prominent objects, such as towers, spires, large stacks, standpipes, etc., that could be identified in the photographs, were located by triangulation.

The Atlantic City project, while demonstrating a possibility of immediate use of aerial photographs, also indicated that there were several problems yet to be solved, and that better methods might be used.

TOPOGRAPHIC REVISION OF THE COAST OF NEW JERSEY.

In March, 1920, the Army Air Service photographed 120 miles of the coast line of New Jersey for the Coast and Geodetic Survey.

FIG. 7.

Mosaic of the New Jersey coast from Corson Inlet to Ocean City.

A single flight was made from Cape May along the coast to Sea Bright, overlapping photographs being taken of practically all of the outer coast line. A De Haviland type, two-seated, photographic plane was used, photographs being made at an altitude of 10,000 feet. A K-1 type camera was used, mounted in gimbals so that it could be kept level by the observer, who watched two level bubbles placed on the camera itself. The photography was done while the plane was en route from Norfolk to New York, and no special field preparation was necessary. The project proved to be a very economical one for that reason. In two hours, 185 overlapping photographs were made, covering the 120 miles of coast line. To survey this same area by the ordinary ground method would require several months' time by one surveying party.

The film was developed in trays, having been cut into lengths about eight feet long for convenience in handling. Developing machines are now used, which lessen the work of handling these 75-foot lengths of film.

Two prints of each film were made for the use of the Coast and Geodetic Survey. One set was used for the construction of strip mosaics, the other set as individual photographs for the study of details or for examination under the stereoscope. Each print has a serial number to avoid confusion in handling.

Strip mosaics were constructed approximately four feet in length. This is a convenient size for handling in the drafting room, and also is the maximum length desirable for use with the pantograph. The mosaics were built up as follows: The end photograph was first glued into position on a mount sufficiently large to hold the complete mosaic, and the adjoining photograph was then trimmed on a line bisecting the overlapping area and fastened to the mount where it joins the first photograph. This process was continued with each photograph in turn until the mosaic was completed. The mosaics varied in length, as determined by the location of the control points, as it was necessary that each of the end photographs should contain a control point. Upon completion of the mosaic, the control points used in previous surveys were identified on the photographs if possible. This was a simple proposition when prominent objects were used, such as lighthouses, spires, etc. After identification of the control points, the distance was measured between each pair of points. The relation between the scaled distances and the actual distances on the

ground was the scale of the mosaic. The reason for measuring all the distances was for the purpose of checking the mosaic to see if it was accurately constructed.

After the mosaic had been tested for accuracy and its scale determined, the pantograph was used to reduce the data to the scale of the chart, which was 1 : 80,000. The pantograph was

FIG. 8.

control point for the Mississippi Delta photographs.   The ordinary triangulation signal does not show in a photograph from the air, but the small shed will show clearly.

reset for each mosaic, as the scale varied slightly between adjoining mosaics. The photographic mosaic pictured topographical features in great detail, but the draftsman selected only the data that are to appear on the chart, such as the shore-line at high tide and at low tide, streets, roads, lighthouses, prominent buildings, wharfs, etc. Some of the features were indefinite, and these were marked for verification in the field. The draftsman made as complete a map as possible, as he knew that this would lessen the work in the field later.

It would be well to mention here the distinct steps necessary in the completion of an aerial survey. They are: First, the photo-

graphic work; second, compilation of as complete a map as possible; third, a field inspection of the photographs, and the field work of establishing suitable control points; fourth, the final, accurate compilation of the data to be charted.

After compiling as much data as possible from the photographs in the office, arrangements were made for the field work. A special holder was made for the strip mosaics to facilitate work on them in the field. It is advisable to examine the mosaics in the field, but not necessary. The individual photographs may be used instead if it is inconvenient to transport the mosaics.

The amount of field work necessary will vary with the locality, quality of the photographs, accuracy of the mosaics, old stations recoverable, etc. The coast of New Jersey is well supplied with triangulation stations, and almost the only field work necessary was to check up the photographs and recover the old stations. After recovering an old station, even if it is in the centre of a field, the locality could be identified in the photograph by comparing the adjoining terrain with the photograph.

Only a few minutes were required to verify doubtful data on the photographs at any particular locality. It was generally a question of interpretation as some terrain was very difficult to identify in the photographs. Tidal flats in particular were difficult to interpret and had to be examined in the field. Generally all that was necessary was to interpret some particular shade in the photograph and its limits could then be easily discerned.

If the previous triangulation stations had disappeared or were of insufficient number, then the field work would have been increased considerably. Additional triangulation would have been necessary. But this triangulation would have been necessary in the same region if a topographic survey had been made from the ground, so this does not represent cost peculiar to aerial surveys.

After the field inspection, the final office reduction was made. This necessitated slight corrections to the preliminary reductions. An estimated cost of the revision of the New Jersey charts by the old methods results in figures that total three times as much as the cost by the aerial method.

MISSISSIPPI RIVER DELTA.

A definite program was planned by the Coast and Geodetic Survey, following the New Jersey work, for the resurvey of the

Mississippi Delta. Early in 1921 arrangements were made for
the aerial survey of the Delta by the Naval Air Service, with the

Fig. 9.
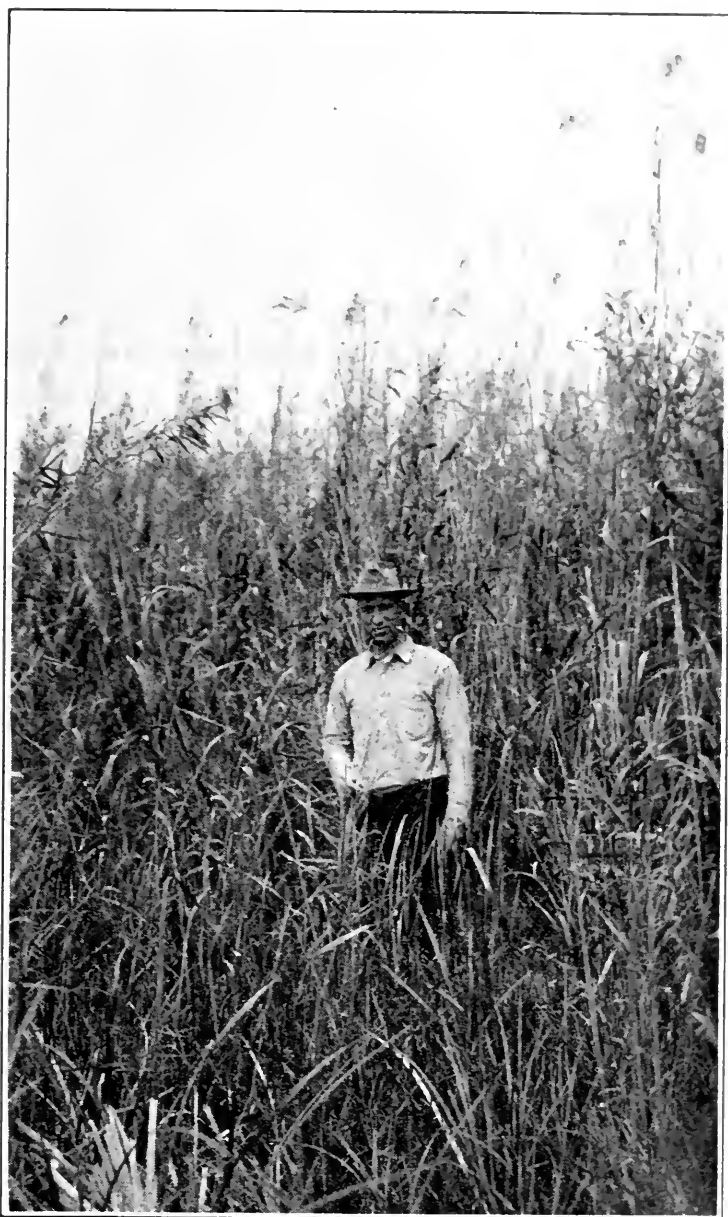
Wild cane.

Engineer Corps of the Army and the Coast and Geodetic Sur-
vey coöperating.

The Mississippi River Delta has grown out into the Gulf of
Mexico from year to year, constantly fed by the sediment carried

down by the river from its upper reaches. The area is low, flat, and marshy, covered almost wholly by a dense growth of cane which attains a height of twelve feet or more. The numerous bayous and passes that thread their way through the marsh are usually lined with willows growing close to the water's edge. While the willows impart a picturesqueness to the streams they also tend to add to the difficulty of the surveyor by interfering with his line of sight. This is not the only factor that hampers the surveyor. The soft condition of the soil and the thickly growing cane render travel by foot a very difficult and laborious process. Previous surveys were made from scaffolds built above the cane and from boats. Practically all travel was by boat, as this is the quickest way to go from one station to the next throughout most of the Delta. Even from the scaffolds some details were hidden from view. Many lakes were missed entirely, as they could not be seen in the sea of cane or were hidden by the willows. The aerial survey discovered scores of lakes unknown before. The advantages of the aerial method over the ground method in this type of terrain are very evident even to the casual observer.

The lower end of the Delta extends approximately 40 miles into the Gulf with an average width of 15 miles, or a total of about 600 square miles. A large portion of this area was photographed in the spring of 1921. Early in November arrangements were made to complete the work, but owing to an accident to the plane the work was not taken up until December.

The Engineer Corps of the Army was anxious for an aerial survey, as it was believed that the photographs would prove of material assistance in coping with some of the engineering problems peculiar to this region. The photographs did bring out several interesting points and have proven very valuable to the engineer. A proper study of the Delta changes necessitates frequent surveys of some sections, and the aerial method is the cheapest and best in that case. The engineer who is interested in physiographic changes finds an aerial survey of immense value. Occasionally features are shown that are missed by a person walking over the ground. Slight variations in color, of vegetation or soil, can be plainly seen in the photographs although often indistinguishable by a person on the ground. This slight variation may be the key to the knowledge of a condition that at one time existed. This has been no more aply illustrated than in the case

where an ancient city in Mesopotamia, of an estimated population
of four million, was surveyed from the air.   What appeared to be

FIG. 10.
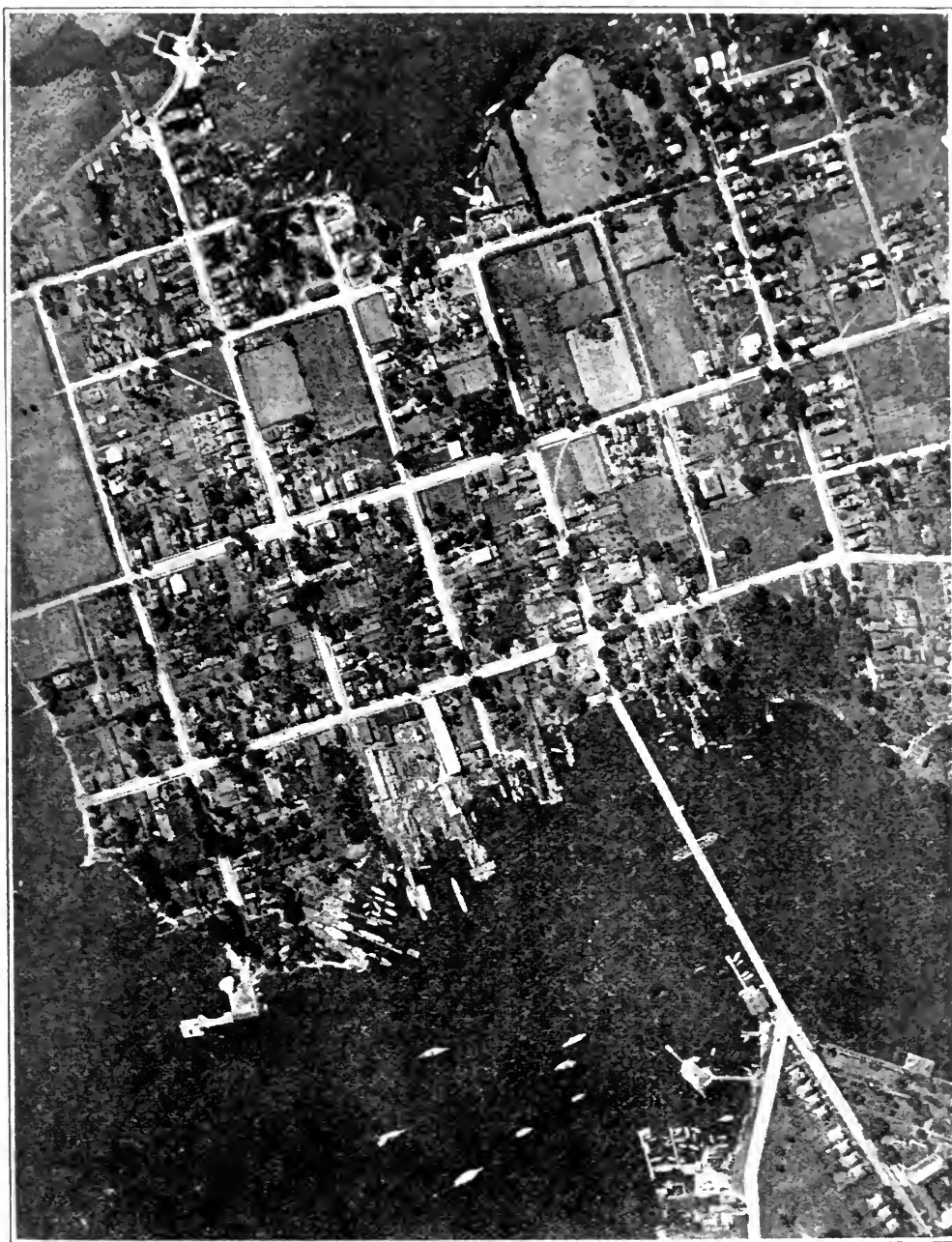
Air view in vicinity of Annapolis, Maryland.

meaningless mounds or blotches of color on the ground took on
a definite form in the photographs, and it proved a comparatively

easy task to distinguish the various details such as outlines of streets, public buildings and houses of various sizes and shapes.

There was no expectation of finding ancient cities on the Delta, but what was more important, old stream beds could be traced. The changes due to overflowing of the banks in some places could be seen. The form of a new sub-delta at a recent break in the bank could be studied. In many different ways was the value of the survey to the engineer demonstrated.

The Coast and Geodetic Survey was primarily interested in producing as correct a chart as possible of the Delta. To this end, a representative of the Survey carried on the necessary triangulation for the control of the photographs, keeping in close touch with the aviators and the Army Engineers so as to supply their needs in regard to control points. The Naval Air Service furnished all the equipment and personnel necessary for the photographic work.

A seaplane equipped with twin floats was found to be the best type of aircraft to use for a photographic survey of the Delta or a similar region. Landing was restricted to bodies of water, which necessitated the use of a seaplane. The boat type of seaplane can be used for mapping, but it requires cutting an opening in the bottom of the boat. A close-fitting water-tight cover must be provided for this opening for use when the plane is in the water, while in a seaplane equipped with twin floats a sliding door to keep out spray is all that is necessary over the camera opening.

The plane used for the work on the Delta was originally designed as a torpedo plane, but was modified for photographic purposes. The pilot's seat ordinarily is in the front cockpit and the observer's in the rear, but this arrangement was reversed for two reasons: First, the extra weight of camera and equipment would be nearer the centre of gravity in the front cockpit; second, the pilot could observe the ground below him better from the rear cockpit, as the lower wing is not in his way. This latter advantage has since been offset by placing a negative lens in the bottom of the plane, through which the pilot can see the terrain immediately below.

A K-1 camera was used for this work. During the first flights the camera was mounted rigidly in the plane, but later was mounted in gimbals. A circular opening was made in the bottom of the fuselage just below the camera through which the photographs

were made. A sliding door over this opening was operated from the observer's seat, and it protected the camera from spray when taking off or landing.

Owing to the fact that the axes of the camera were fixed in relation to the plane, it was necessary for the aviator to exercise great care in operating the plane in order to approximate a stabilized camera. The ordinary level vials used on all planes, and installed on the instrument board in front of the pilot were the only indicators of the verticality of the camera. It is evident from the results of the work that in the hands of a clever pilot exceptionally good results can be obtained in this manner, but still this cannot be compared in effectiveness to a gimbal mount.

The lack of an up-to-date chart proved a handicap to the aviator. Although the main river and the important passages have been recently surveyed from the ground, some of the un-important areas have not been surveyed for fifty years. Many changes have occurred in that time, in some areas very markedly. The only map available for the aviator to use as a guide was the chart as issued by the Coast and Geodetic Survey. Some sections had changed completely, so the chart was of very little value to him except along the shore-line of the main channels. It was almost impossible to plot courses for flights. He depended on his memory as to the area covered by each flight. He was quite successful in this in spite of the fact that it was his first extensive map-ping project.

Weather conditions interfered much with aerial photography. During the latter part of March, all of April, and the early part of May, during which time the work on the Delta was in progress, only 16 days of a total of 47 were suitable for photographic map-ping owing to cloudy and hazy weather. Five of the 16 were Sundays, and on three other good days the plane was out of com-mission due to the necessity for repairs. Therefore, there were only eight available photographic days in the 47.

The Engineer Corps, with the idea in mind of obtaining suffi-cient detail, requested that the photographs for them be made at an altitude of 5000 feet. The Coast and Geodetic Survey asked for photographs at a higher altitude, as this generally produces better results. Eight thousand feet was decided on as the altitude for the photographs covering the areas not included in the 5000-foot set. The Engineers were interested in the South and Southwest

Passes and the new sub-delta formed in Bird Island Sound. These areas were the first to be completed.

An interesting comparison can be made as to the area covered at the two altitudes. Nine hours' flying was required for the 5000-foot project covering 57 square miles, while nine and one-half hours at the higher altitude resulted in photographs of 175 square miles. In other words, about three times the area was photographed at 8000 feet as was covered in about the same time at 5000 feet.

All the flights were not made in the same direction. The direction of the wind governed the course for the day, and the locality chosen for photographing was that best suited for the particular courses. A pass was usually selected as a guide for the first flight, and the other flights were made parallel.

After completing the preliminary photographic work in the spring of the year, the prints were used by each of the bureaus according to its individual needs. Mention will only be made here of the work of the Coast and Geodetic Survey.

With the idea in mind of compiling as correct a chart as possible within a short interval of time, the necessary office work was started as soon as the prints were received. A revised chart was constructed for the use of the aviator in continuing his work, and was accurate enough for the use for which it was intended.

Mosaics were constructed of as large a size as could be conveniently handled. The scale of the mosaic was determined as accurately as possible by measuring between points of the photographs, the geographic positions of which were known. Knowing the scale, the mosaic was reduced photographically to the scale of 1 : 80,000, which is the scale of the chart at present issued. A tracing was then made of all the topographic features in the reduced photograph and the data transferred to the chart. Usually there were enough control points, or unchanged features, so that the tracing could be fitted in its exact position on the chart and the changes noted and transferred to the chart.

It was necessary to construct 13 different mosaics in order to include all the photographs. The results obtained were very good, considering the rapid manner in which the mosaics were constructed. They varied slightly in scale, but adjustments were made to compensate for this.

In addition to the preliminary revision, an index chart was also

made. This index chart is not only convenient for filing with the collection of photographs, but also is a practical subject for study by aviators interested in mapping from the air. It visualizes some of the difficulties attendant on a photographic project in territory

FIG. 11.
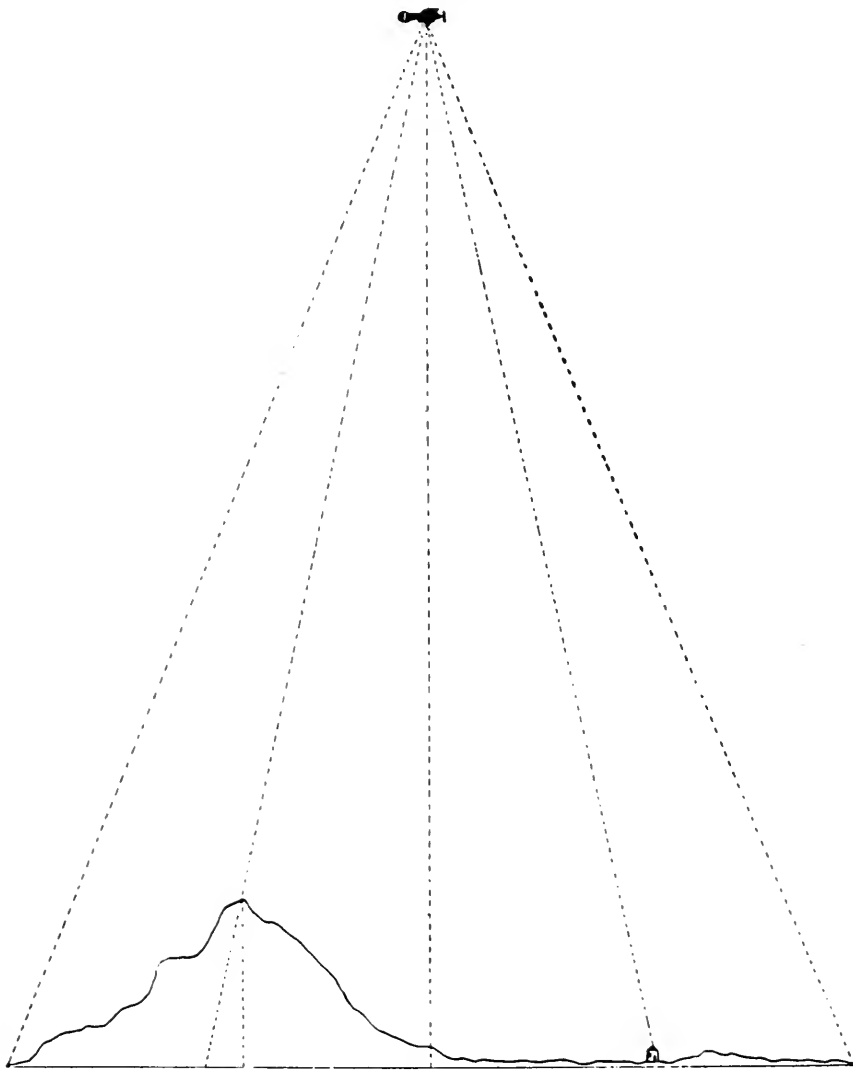
Horizontal displacement due to relief.

where there are no regular features to serve as guides in flight. The effect of " crabbing " is clearly shown. The relative areas covered by the photographs at 5000 feet and at 8000 feet are here shown in a way that demonstrates one of the advantages of the higher altitudes.

A complete up-to-date chart of the Delta has never been issued. Surveys extending over a period of years have been combined, but

owing to rapid changes continually occurring, the earlier surveys would require corrections by the time the last one was completed. A complete aerial survey, which required only eight or ten days' flying, will give a correct chart of the Delta as a whole for the first time.

EXPERIMENTS IN UNDER-WATER PHOTOGPAPHY.

During the war the Naval Air Service made successful photographs of under-water objects. Submarines were photographed below the surface. In the clear waters of the California and Florida coasts, photographs were made of the ocean bottom where the water was only a few feet deep. The possibilities of usefulness for survey purposes seemed favorable, so arrangements were made for experiments in the vicinity of Key West, Florida.

The water in the vicinity of the Florida Keys is very clear, it being possible to see the bottom in depths of 50 or 60 feet or more from the deck of a vessel. The bottom is broken up by irregular growths of coral. Sometimes a small coral head only 4 or 5 feet in diameter rises almost to the surface. The wire drag is essential in this type of ocean bottom for locating all coral shoals. It was hoped that aerial photography would replace some of the wire-drag work, possibly all, as the clear waters seemed to be admirably suited to photographic work.

The experiments were carried on during the month of July, 1919. Haze and cloudy weather interfered considerably with the work, resulting in only four days' photographic work being done. During certain seasons unfavorable meteorological conditions seem to be the rule along the seacoast, and any photographic work undertaken should be planned for those seasons when there will be the least delay owing to bad weather.

A two-seated Naval seaplane, manned by Navy personnel, was used for the photography. The photographs were made at altitudes varying from 500 feet up to 4000 feet. Some photographs were made pointing vertically down, others at small angles with the vertical, and still others, made with the hand-held camera, were at the usual angle for taking obliques. An L type camera was used at first, but some trouble developed with the mechanism, so a Navy type hand-held camera and an ordinary Graflex were used for the remainder of the work. Various types of filters and plate emulsions were tried under the different light conditions.

In order to approximately orient the photographs, it was neces-
sary to know the geographic location of at least two points on each
photograph. As the area photographed was several miles from the
nearest islands, it was necessary to have two boats in each picture.
Two survey boats travelled on parallel courses about 400 yards
apart, and on each boat sextant observations were made to de-
termine the exact position at frequent intervals. In this way the
position of each boat could be determined at any particular instant,
and as the photographer in the plane recorded the time each photo-
graph was made the photographs could be oriented from the posi-
tion of the two boats shown in them. As the boats travelled at 8
miles an hour, and the plane at 55, it was necessary for the plane
to fly forth and back, exposing a plate every time it passed over
the boats.

While photographs were made of the bottom through 30 or 40
feet of water, it was demonstrated that aerial photography was not
a practical method to use, as the results were too uncertain. It is
possible that, with further development of photographic methods
and equipment, more positive results will be obtained. It would
be a natural supposition to expect that shoal areas would show in
sharp contrast to the surrounding deeper area, as the light rays
travelled through different amounts of water. It was also expected
that a shoal, being of different color than the ocean bed in the im-
mediate vicinity, would be plainly indicated. The results obtained
were very confusing. Level bottom appeared as being dotted with
shoals, which upon investigation proved to be due to vegetation
growing on the bottom or else to vari-colored bottom. Shoals,
whose locations and depths were known from hydrographic sur-
veys, could not be found in the photographs. The condition of
the surface of the water seemed to affect the visibility of the
under-water features, as did also light conditions. In fact, the
limiting conditions necessary for good photographs, with the
uncertain results, proved to be too strong an argument against
aerial photo-hydrography. There seems to be a limited field of
usefulness in the photography of possible channels in sedimentary
rivers, or in shoal water bays, but even this will eliminate very
little field work. We must continue to take soundings and do wire-
drag work.

CONCLUSION.

Aerial surveying has proven its worth. Speed, economy and multiplicity of detail are strong arguments in its favor. Relieving the surveyor of disheartening labor in territory verging on the inaccessible, but now limited to flat terrain, it is probable that it will soon be developed to the stage where it can be used in mountainous territory with further lessening of the hardships incidental to mapping. There are thousands of square miles of level terrain where aerial photography can be advantageously used at the present day.

The Coast and Geodetic Survey has no desire to enter the field of aviation, as no doubt the two Air Services should be able to furnish all the photographs needed, at the same time keeping their personnel in training. Lack of appropriations has hindered those services so far, but it is hoped that the future will bring better conditions.

The Coast and Geodetic Survey has the chart compilers, some of whom were trained in interpretation of aerial photographs during the war, while others have studied the subject since that time. If the Air Services will furnish the photographs, the necessary office work and the supplemental ground surveying will be done by the Coast and Geodetic Survey, and the charting of our coasts will be expedited.

The Relative Affinity of Some Gas Molecules for Electrons. L. B. Loeb. (*Phil. Mag.*, January, 1922.)—"In some gases the electron must on the average make a number of impacts n with the molecules of the gas before it can strike one in such a manner as to attach to it to form the negative ion." The present paper has for its purpose the determination of this quantity, n, for some gases. The way to the result is not an easy one. It is hedged with exponential formulas and menaced with uncertainties, yet this rather astounding conclusion comes forth—"In spite of the difficulties in determining its value accurately, the constant of electron attachment, n, is, even in its order of magnitude, a marked and characteristic property of the different kind of gas molecules." For N_2 and H_2 it comes out infinite, which means that these molecules never annex an errant electron. For CO it is 160,000,000 and for Cl_2 it is 2100 or less.

The suggestion is thrown out "that n is dependent on either the electrons striking a particular point in the atom, or in its striking a molecule in some particular state of physical or chemical activity."

G. F. S.

CHANGE OF THE PHYSICAL PROPERTIES OF MATERIALS WITH PRESSURE.*

BY

ERSKINE D. WILLIAMSON, B.Sc., M.A.

Physical Chemist, Geophysical Laboratory, Carnegie Institution, Washington, D.C.

In the Geophysical Laboratory our sphere of inquiry includes all questions relating to the chemistry and physics of the processes occurring in the earth's crust. Since pressure is a factor which cannot be neglected in considering reactions which occur at any great depth beneath the surface, our attention has been directed for some time toward devising ways and means of carrying out exact experimentation under the greatest possible range of pressure, as well as of temperature, which may be compassed conveniently in laboratory practice. In most cases our final aim has been chemical rather than physical, but a number of points have been touched which are interesting to students of exact science in general. The object of the present paper is to collect certain results of this nature obtained by ourselves or others showing the general effects of high pressure on the more fundamental physical properties.

At the outset special mention must be made of the series of papers published in the last fifteen years by Dr. P. W. Bridgman. These furnish a veritable mine of information on the subject in hand and have already led to many valuable results. Individual papers will be continually referred to throughout this review.

For the sake of the reader who is not familiar with the technic of modern high-pressure work the range of experiment will be roughly indicated. With the materials which are convenient for use at present, exact measurements at ordinary temperatures are rarely made at pressures exceeding about 12,000 atmospheres or 200,000 pounds per square inch. For special reasons a few results have been obtained at pressures considerably higher, but the wear and tear on the apparatus offsets the advantage gained by the greater range. At higher temperatures practical difficulties prevent the use of more than a moderate pressure. At the

---

* Presented at a meeting of the Section of Physics and Chemistry of The Franklin Institute held Thursday, December 15, 1921.

highest temperature at which we have experimented, about 1300° C., a pressure of 1200 atmospheres has been used—that is, about one-tenth of the maximum at room temperature.

The difficulties of making exact measurements of any physical quantity whatever under the conditions outlined are very considerable and much time is consumed merely in devising tools for the enterprise. The glass test-tube of the ordinary chemical laboratory must be replaced by stout-walled steel vessels, generally called bombs, tightly sealed, so that most of our observations have to be indirect. Measurements of some electrical quantity or of the motion of a piston are practically the only feasible ones, except at lower pressures, where optical methods may be used if the bomb be fitted with small windows. Such windows are really just small cylinders of glass held in place by some form of packing similar to those used for holding the electric connections. Dr. W. Wahl [1] has used these devices up to pressures of 4000 atmospheres in some chemical work.

A diagram of one of the bombs used in the determination of the simpler quantities is shown in Fig. 1. It is essentially a steel test-tube with thick walls. The only measurements made, when experiments are performed with this bomb, are of pressure and piston displacement so that it is used for the determination of the changed volume of the contents of the bomb under pressure. The change of volume is measured directly by means of the motion of the piston and the pressure is measured on a secondary gauge which will be described later. The exactness of the volume measurement is dependent on having an absolutely leak-proof packing for the end of the piston. Such packings have been most ingeniously developed by Bridgman.[2] The details of one type are shown in Fig. 2. The most necessary feature is that the external pressure holding in the packing acts through washers which have a smaller area than that on which the internal pressure acts, so that the pressure per square inch on the washers is greater than the pressure inside the bomb. Well-made packings of this nature are completely leak-tight.

A primary desideratum for pressure work is, naturally, a convenient means of measuring the pressure set up in the bomb. It is not generally sufficient to measure the pressure on such a

[1] W. Wahl: *Phil. Trans.*, Series A, 212, 117.

[2] *Proc. Am. Acad. Arts. Sci.*, **49**, 627, 1914.

piston as that in the bomb illustrated since the friction between
the packing washers and the bomb may amount to several hundred
atmospheres, as shown by the difference in external pressure
while the piston is ascending or descending. At low pressures a
procedure frequently used is to balance the pressure by means of

FIG. I.
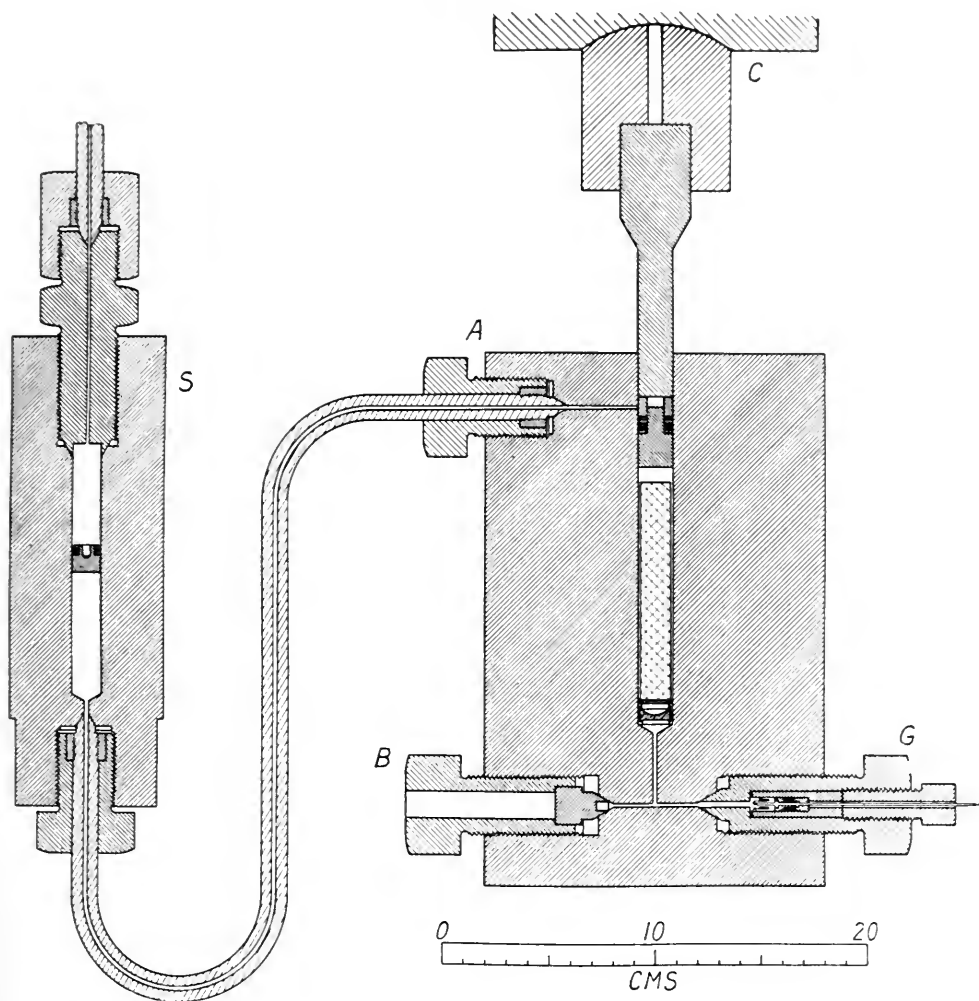
Diagram of bomb and connections to scale as shown. The specimen to be experimented
on is placed in the hole in the thick-walled steel cylinder and surrounded with kerosene. The
plunger is forced downward by means of a hydraulic press and the pressure thereby produced
is measured by means of the resistance gauge G. When the plunger is near the top of its stroke
an initial pressure may be applied by pumping liquid through the extra container S and the
by-pass A by means of an ordinary compression pump. The motion of the plunger is measured
by a dial gauge not shown in this diagram.

a mercury column, but this is available only up to a few atmos-
pheres. The most general type of absolute gauge is that in which
the pressure is weighed on a small movable piston of known cross-
section. Fig. 3 illustrates a suitable design. In using such a
method there is of necessity a slow but continuous leak round

Fig. 2.
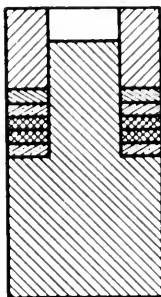
(Actual size).   Packing regularly used to make movable piston pressure tight. Over the stem of the plug beginning at the top is a hardened steel collar, a soft steel washer, a copper washer, two rubber washers and another copper washer.

Fig. 3.
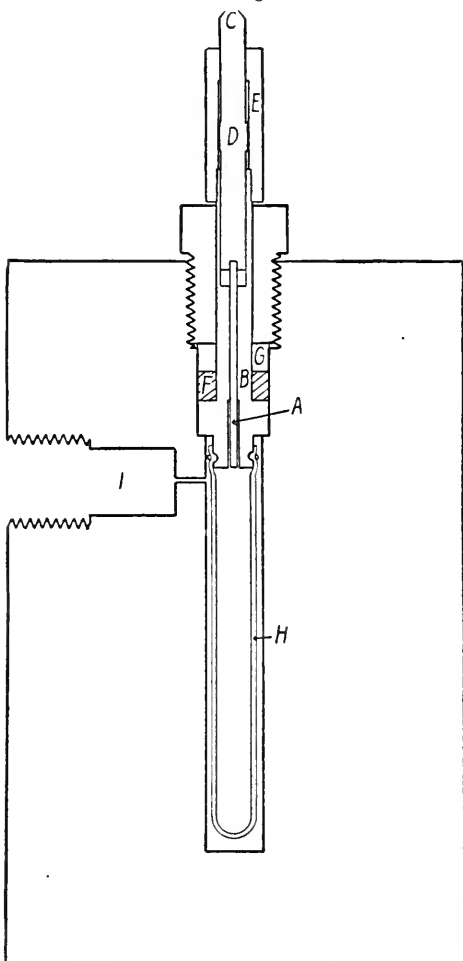
Absolute gauge as used by Bridgman (*Proc. Am. Acad. Arts Sci.*, 44, 205, 1909).   A, piston; B, cylinder; C, hardened steel point on which the equilibrating weights are hung; H, easily collapsible rubber tube containing a viscous liquid.   The pressure vessel is connected at I.

the moving piston, so that it is not in all cases a convenient scheme to adopt. Such an absolute gauge is still a necessity, however, for the calibration of convenient secondary gauges for use in

the bulk of the experimental work. A secondary gauge consists of an instrument for measuring some fundamental property, the change of which with pressure has been previously determined, using the primary gauge as pressure indicator. The property usually chosen is the electrical conductivity of a small coil of wire. Fig. 4 illustrates the arrangement used in the Geophysical Laboratory and Fig. 5 shows the coil in place in the bomb. For measuring pressures up to 100 atmospheres an ingenious secondary gauge has been used quite recently at Johns Hopkins

FIG. 4.
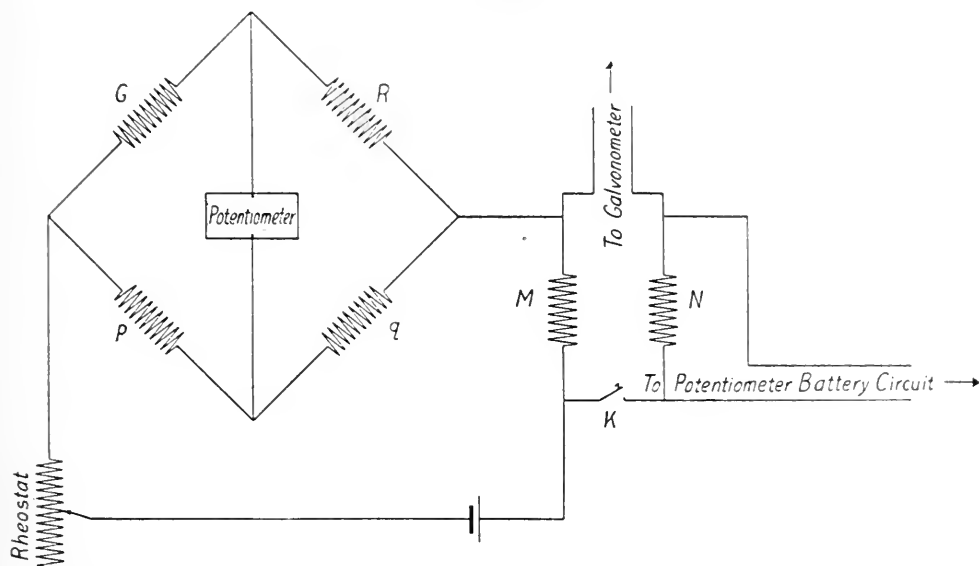
Diagram of bridge connections used for measuring changes of resistance of therlo pressure gauge. A variation in the resistance of the gauge coil G gives rise to an e.m.f. which is read by the potentiometer. Constancy of current ratio is obtained by equalizing (1) the drop in potential across M, a coil in series with the bridge, and (2) the drop in the coil N which is in the potentiometer battery circuit.

University. It consists merely of a water interferometer[3] in which the water in one of the optical paths is subjected to the pressure in the system.

It is now becoming possible to calibrate a secondary gauge by means of fixed points much as a thermometer is calibrated. This will no doubt be the general method in the future. To make this a reasonable procedure it is necessary to determine with the greatest possible accuracy a sufficient number of transition points under pressure to act as the fixed points in a rôle exactly analogous to that of the melting points of pure substances as used in high temperature work. Bridgman[4] has determined a number of

[3] Von Doren, Parker, and Lotz: *J. Am. Chem. Soc.*, 43, 2497, 1921.
[4] *Phys. Rev.*, 3, 126, 1914; 6, 1, 1915.

such points, but these should be independently verified, all precautions being taken as regards chemical purity so that the most suitable and most accurately defined points may be chosen. The freezing pressures of water [5] and of mercury [6] give two excellent points at fairly high pressures.

The change of electrical resistance with pressure will be taken as the first example of the action of pressure on a physical prop-

FIG. 5.
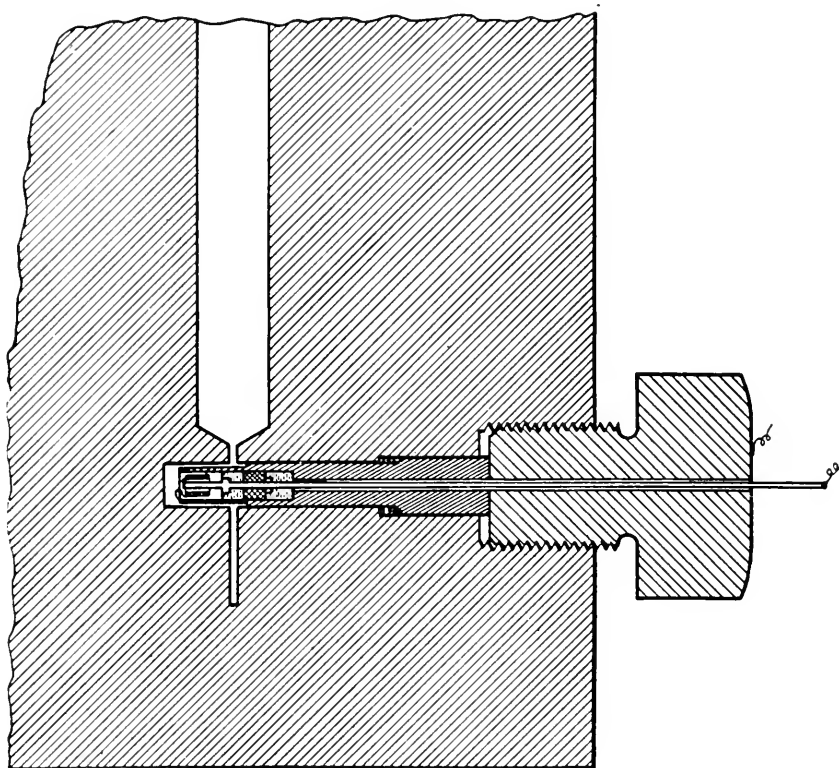
Section through lower half of bomb showing details of our most recent pressure gauge.

erty. Since metals are the commonest conductors they will be treated first.

Alloys which have a very low temperature coefficient of change of resistance are most easily experimented upon as the system of temperature control need not be so perfect. The alloys known as manganin and therlo have been specially investigated, as they have been used for the making of the secondary gauges already mentioned. Both have low temperature coefficients, while therlo has the advantage of its low thermo-electromotive force against

[5] P. W. Bridgman: *Proc. Amer. Acad. Arts Sci.,* **47**, 517, 1912.
[6] P. W. Bridgman: *Proc. Amer. Acad. Arts Sci.,* **47**, 417, 1911.

copper. The change of resistance for these alloys under pressure is very small—of the order of two parts per million per atmosphere—and is positive, that is, the resistance increases with the pressure. In the case of manganin the change is linear, but in the case of therlo the resistance increases more rapidly for the first few hundred atmospheres when the relation becomes practically linear for at least 10,000 atmospheres. Table I shows a typical calibration table of one of our therlo gauges.

The resistance of pure metals in general decreases with the pressure. Bridgman[7] showed some years ago that antimony

TABLE I.

Calibration of Gauge.

Pressure megabars	Electro-motive force microvolts
0	0
1,000	1,141
2,000	2,291
3,000	3,448
4,000	4,609
5,000	5,769
6,000	6,928
7,000	8,085
8,000	9,241
9,000	10,396
10,000	11,549
11,000	12,701
12,000	13,851
13,000	15,000
14,000	16,148

and bismuth are exceptions, and more recently[8] lithium, calcium, and strontium have been added to the list. Great care must be taken with the temperature control in experiments on pure metals since the coefficients are usually such that a difference of $0.001°$ C. makes about as much difference as a pressure of one atmosphere. The rate of change of resistance is a rather small quantity, being measured in parts per million per atmosphere, and as the pressure increases this rate becomes still smaller. Table II contains a number of results from the papers already referred to. I am not

[7] *Proc. Am. Acad. Arts Sci.,* **52,** 573, 1917.
[8] P. W. Bridgman: *Proc. Am. Acad. Arts Sci.,* **56,** 61, 1921.

aware of any practical use that has been made of this property except that already mentioned of making secondary pressure gauges. It may be, however, that such a method of obtaining reproducibly very small changes of resistance will find future uses. On the theoretical side we are led to test the various theories of electrical conduction to see if they can give a satisfactory

TABLE II.

Changes of Resistance of Metals with Pressure.

Metal	Ratio of resistance at 12000 kg. per sq. cm. to resistance at 1 kg. per sq. cm.
Lithium	1.0927
Sodium	0.5854
Potassium *	0.2748
Magnesium	0.9510
Calcium	1.1550
Strontium	1.8160
Tungsten	0.9838
Mercury (liquid)*	0.7377
Bismuth	1.2672
Tin	0.8895
Cadmium	0.8927
Lead	0.8546
Zinc	0.9436
Aluminum	0.9542
Silver	0.9600
Antimony	1.1464
Copper	0.9780
Nickel	0.9823
Cobalt	0.9895
Iron	0.9729
Platinum	0.9776

*The temperature during experiment was 0°C. except in the case of mercury and potassium in which it was 25°C.

account of the changes observed. These considerations have led to a very much modified theory.[9] The underlying idea is that electrons can move freely in the interiors of atoms but have difficulty in jumping from atom to atom. Conduction is thus mainly a function of the average distance apart of the atoms and the amplitude of the atomic vibrations. The classical expression

[9] P. W. Bridgman: *Phys. Rev.,* **9,** 269, 1917, and **17,** 161, 1921; especially the latter.

for the resistance will still hold under the newer theory, namely,

$$R = \frac{2\,mv}{e^2 nl}$$

where e is the charge on an electron, m the mass of an electron, n the number, l the mean free path and v the velocity of the electrons. The difference lies in the fact that the mean free path has a much larger value than in the classic theory, being bounded now not by collisions, but by gaps between atoms.

Metals which have only one electron in the outer shell of their atomic structure are the best conductors as they give the largest value of n. If a good conductor like copper is contaminated with an even better conductor like silver or gold the conductivity is cut down not because of any great difference in n, but because the atoms do not fit so well in the general structure so that gaps are increased and l is correspondingly diminished.

Quantitatively considered the theory yields the known results such as Ohm's law and the general law for pure metals that the temperature coefficient of electric resistance is inversely proportional to the absolute temperature. Qualitatively it can be shown that the less well-known pressure effects are at least not in conflict with it, which statement is not true as regards any of the older theories. It was, of course, these pressure effects which led to the formulation of the theory, and if that was the only result obtained from high-pressure work it would of itself be sufficient to justify all that has been done in this field. It is not the part of this communication to discuss the matter at greater length. Those who wish further information will find it in the papers already quoted.

Measurements have been made of the effect of pressure on another fundamental electrical quality, namely, the thermo-electromotive force [10] at a junction of two metals, and from these results the effect on the value of the Peltier and Thomson heats can be calculated. It was hoped that this study would cast a considerable amount of light on questions as to the nature of electrical phenomena in metals. In general one may say, however, that the results from this point of view were negative. It can be shown that none of the simple theories proposed, such as the free gas electron one, is at all competent to explain the observed facts.

---

[10] P. W. Bridgman: *Proc. Am. Acad. Arts Sci.*, 53, 269, 1918.

Bridgman says: "The unexpected complications found makes these results disappointingly meagre in their suggestions as to the nature of the thermo-electric mechanism. The conclusions are mostly negative in character. The most unmistakable inferences may be drawn as to the untenability of the old gas-free electron theory of metals, but this is not now new enough to be worth the experimental trouble. This conclusion was drawn ten years ago by Wagner from his data up to 300 kg. and the results of this paper can add nothing to the conclusions of

TABLE III.

Electrical Resistance of Solutions.

Temperature, 25° C.; Salt, NaCl.
Concentration, 0.292 Per Cent.

Pressure megabars	$R_x/R_{x=1}$
I	1.0000
497	0.96636
997	.94552
1522	.93410
1869	.93100
2127	.93048
2404	.93158
2680	.93416
3470	.94826
4161	.96796
3101	.94028
1967	.93006
I	.99984

Wagner in this regard, since our results are in essential agreement over our common range. Further than this, the results suggest most strongly that the thermo-electric mechanism must be comparatively complicated, that it cannot be at all of the simplicity imagined by the free electron theory and that most likely the effects which we measure are the resultant of different effects which, sometimes at least, work in opposite directions!" The later views on conductivity already mentioned may lead to a much better theory of the Thomson and Peltier effects and there are at least no contradictions.

The electrical conductivity of solutions has been a subject of

much study. Cohen and Schut [11] have collected the older results. In dealing with this subject we find factors which do not enter into the question of conductivity in solids, but on the other hand, the matter is in some ways less complicated. The effects of pressure on such conductivity may be grouped under the following heads :

(1) By the compression of the solution the number of ions per unit volume will be increased.

(2) The degree of dissociation of the dissolved substance may change. It may decrease or increase, but is subject to thermodynamic laws. The governing factor is the change of volume involved.

(3) The degree of hydration of the ions may change. This is subject to the same laws that operate in condition (2).

(4) The internal ionic friction changes, being probably connected with the viscosity.

(5) The small part of the current carried by the solvent may also be changed for reasons similar to the above.

For very dilute aqueous solutions in which the salt is completely dissociated one might expect offhand that the conductivity would change in exactly the same ratio for different salts, at least when allowance has been made for the slight differences of compressibility. This is found, however, *not* to be the case. We are thus driven at once to the conclusion that the changes in the internal ionic friction and the viscosity of the solvent water do not run parallel, but the former must depend in some way on the solute. The atomic weight may be one of the deciding factors. For example, if we make equally dilute solutions of the chlorides, bromides, and iodides of sodium and potassium, and draw curves [12] showing the per cent. change of resistance with pressure, the curve for a sodium salt will always lie above that of the similar potassium salt while considering salts of the same metals the curves will lie in the order—chloride, bromide, iodide—the last lying above the others.

In the Geophysical Laboratory we are attempting to make more accurate measurements than have so far been made, over a more extended pressure range, but qualitatively our results resemble the older ones. One of the features of our apparatus

[11] Cohen and Schut : *Piezochemie. Akad. Verlag.,* Leipzig, 1919.

[12] Cohen and Schut : *Op. cit.,* p. 309.

is the use of a very small cell current which is made possible by the use of an amplifier [13] in the galvanometer circuit. This is, so far as we know, the first application of such an amplifier to this kind of work. The use of a small current is of great assistance in minimizing temperature disturbances.

The curves in Fig. 6 show the nature of the results [14] obtained. For dilute solutions the resistance at first decreases and then, after reaching a minimum value, begins to rise rather rapidly. For

TABLE IV.

Electrical Resistance of Solutions.

Temperature, 30° C.; Salt, NaCl.
Concentration, 20.259 Per Cent.

Pressure megabars	$R_x / R_{x=1}$
I	1.0000
250	0.99922
495	0.99968
759	1.0011
1035	1.0038
1522	1.0112
2059	1.0227
2470	1.0334
3102	1.0534
3525	1.0689
3980	1.0869
2845	1.0449
1845	1.0174
881	1.0017

strong solutions, on the other hand, the resistance increases at once. There is an intermediate solution where the initial effects just balance and the resistance does not change for the first small amount of pressure. The middle curve of the three almost meets this requirement. Table IV shows how nearly this is true—the resistance varies only one-tenth of one per cent. in the first seven hundred megabars.

The main effect observed in all cases seems to be a change of internal friction which in dilute solutions decreases to start with and then at higher pressures increases rapidly.

---

[13] R. E. Hall and L. H. Adams: *J. Am. Chem. Soc.,* **41,** 1515, 1919.

[14] From some experiments by Dr. R. E. Hall—as yet unpublished.

Leaving the discussion of electrical properties and turning to the field of elasticity, we find that the cubic compressibility is the most natural first subject for study. It is well known that for "perfect" gases the isothermal compressibility is inversely proportional to the pressure, but as regards other substances the average person's knowledge is in many cases limited to the old school dictum that "liquids are incompressible." In reality, of course, no substance is completely incompressible, and if one is

TABLE V.

Electrical Resistance of Solutions.

Temperature, 25° C.; Salt, NaCl.
Concentration, 23.983 Per Cent.

Pressure megabars	$R_x/R_{x=1}$
1	1.0000
265	1.0023
505	1.0055
768	1.0100
1020	1.0153
1258	1.0211
1529	1.0285
2106	1.0473
2557	1.0645
3155	1.0903
3533	1.1082
3912	1.1267
2663	1.0686
1725	1.0340
823	1.0105
378	1.0032

thinking of liquids not in comparison with gases but with solids, one is more apt to think of a liquid as a rather highly compressible substance.

The bomb already shown in the first diagram is excellently adapted for the required measurements. The photograph shows the apparatus as actually used. In general two sets of readings are taken, in one of which the substance which is being experimented on is placed in the bomb entirely surrounded by oil, while in the other a piece of steel of the same initial volume is substituted. The difference of piston displacement in the two cases gives directly the difference between the change of volume of the

substance and of the steel piece. The use of this bomb is described in various publications.[15]

The effect of pressure on the compressibility is to diminish it. That is, for any substance the change of pressure produces a diminishing change of volume. In the case of liquids this effect

TABLE VI.

Volume of Water as a Function of Temperature and Pressure.

Pressure kg. per sq.cm.	Volume		
	0°C.	20°C.	40°C.
0	1.0000	1.0016	1.0076
500	.9771	.9808	.9873
1,000	.9578	.9630	.9700
2,000	.9260	.9327	.9403
3,000	.9015	.9087	.9164
4,000	.8807	.8880	.8956
5,000	.8632	.8702	.8778
6,000	.8480	.8545	.8623
7,000	....	.8404	.8485
8,000	....	.8275	.8360
9,000	....	.8160	.8249
10,000	....	....	.8149
11,000	....	....	.8056
12,000	....	....	.7966
12,500	....	....	.7922

is very noticeable as can be immediately seen from Tables VI and VII, which show some results for water and for kerosene. In the case of water at 40° C., for instance, as shown in Table VI, the first 500 kilos of pressure produces a change of volume of the water of 2 per cent., while the 500 kilos from 12,000 to 12,500 produces about 0.5 per cent. The same behavior may be noticed in the case of solids, except in the case of a few for which the change is so small that it cannot be detected with our present limits of accuracy. Richards [16] and his pupils, although only working at low pressures, have showed the effect for a number of the more compressible metals, while our results at the Geophysical Laboratory show it for almost all the substances experimented on.

---

[15] Adams, Johnston and Williamson: *J. Am. Chem. Soc.*, **41**, 12, 1919. Adams and Williamson: *J. Wash. Acad. Sci.*, **9**, 30, 1919. L. H. Adams: *J. Wash. Acad. Sci.*, **11**, 45, 1921.

[16] Richards: Various papers in *J. Am. Chem. Soc.*

The least compressible substance known is diamond. This had been predicted on the basis of the various approximate formulæ [17] linking the compressibility with other physical constants such as the melting point. Direct measurements made here verify the prediction. A hydrostatic pressure of one megabar decreases the volume of a diamond by barely two parts in ten million, so the highest pressure obtainable in the laboratory can only compress a diamond by a fraction of one per cent.

In Table VIII there are presented a number of our results. Some of these have been published in the papers already quoted, while others are results as yet unpublished. The result for diamond

TABLE VII.

Compressibility of Kerosene at 20° C.

Pressure megabars	Fractional change of volume between 2000 megabars and P. megabars
12,000	0.150
11,000	0.142
10,000	0.133
9,000	0.123
8,000	0.111
7,000	0.098
6,000	0.084
5,000	0.068
4,000	0.050
3,000	0.027
2,000	0.000

is a new one and is the mean of three results, the two more recent being determined by experiment on rather more favorable material than was available when L. H. Adams (*op. cit.*) published his preliminary value. The change in the compressibility is tabulated, except when the results were irregular owing to the material not being quite homogeneous so that no accurate estimate of the change could be made. In general the less compressible substances show less change of compressibility, but this is not without exception and in any case there is no approach to proportionality of the two quantities.

When more accurate measurements can be made we shall have a useful check on theories of atomic attraction. X-ray analysis has elucidated the arrangement of the atoms in many of the simple

---

[17] L. H. Adams: *Op. cit.*

crystals so that the compressibility, and more especially the change of that quantity with the small changes in the packing of the atoms brought about by the compression, will give some idea of the laws governing the forces of attraction or repulsion. Born and Landé have already made some use of the compressibility in this connection, but the check is not a competent one owing to the insufficient degree of accuracy of the experimental results.

TABLE VIII.

Compressibilities and Changes of Compressibility of Solids.

Material	Compressibility per megabar x 10^6	
	at o megabar	at 10,000 megabars
Diamond	0.18	0.18
Sodium chloride	4.12	3.53
SiO_2, glass	3.1	...
SiO_2, quartz	2.70	2.31
Bismuth	3.00	2.57
Cadmium	2.24	1.70
Lead	2.21	2.16
Tin	1.89	1.64
Zinc	1.74	1.43
$CaCO_3$, calcite	1.39	1.39
Aluminum	1.32	1.32
Silver	0.97	0.97
Copper	0.75	0.75
Gold	0.57	0.57
Marble *	1.41	1.41
Granite *	2.13	1.84
Basalt *	1.88	1.55
Diabase *	1.26	1.26
Plate glass *	2.27	2.05
Cast iron	0.89	0.76

*The first column gives the compressibility at 2000 megabars in these cases.

The change of compressibility has not been examined from this point of view so far as I know.

In the case of rocks there is a line of evidence about the value of the elastic properties under a far greater range of conditions than is possible in the laboratory. I refer to the use that may be made of observations of earthquake waves. As is well known, seismographic records are obtained at many stations all over the earth whenever an earthquake occurs, but the nature of these records and the deductions to be made therefrom are not so generally known. The characteristic tremors which reach a station

consist of three parts: (a) Vibrations similar in character to the sound waves in air; (b) transverse vibrations analogous to light waves; (c) waves which have traveled over the surface of the earth. The last of these three produces the main shock, but our present interest is only in the first two, which have passed through the earth roughly speaking along chords of a circle. The velocity of the wave fronts depends on the density of the material through which they are passing as well as on its compressibility and rigidity. By observing the time of arrival of the disturbances at stations at different distances from the centre of the earthquake activity, a series of observations is obtained from which the wave velocity at any depth may be calculated. The details of the computations involved are not of interest here, but it should be mentioned that only one assumption is involved—namely, that the velocity is simply a function of the depth or, in other words, that the velocity at a depth of a certain amount is the same at all latitudes and longitudes. It is evident that close to the surface this postulate is not justified, but since the velocity of the waves is several miles per second and as the surface layer includes only a small part of the path of a wave which has come through from a distant point, this does not invalidate the results obtained.

After having computed the velocities of the two waves at all depths we are provided with two relations connecting the density, compressibility, and rigidity of the material of the earth. Some idea of the distribution of density can be obtained from astronomical data, and if this distribution could be accurately obtained, it would be possible to calculate the elastic constants. Since at present the density distribution is not sufficiently well known, it is only possible to calculate the ratio of these constants. Table IX gives the values of the velocity of the compressional wave at various depths and also of what is known as " Poisson's ratio," [18] which can be obtained unequivocally. It is noteworthy that while the velocity changes enormously, the ratio of the elastic constants remains almost constant. To give some idea of the pressure range covered by these results from earthquakes, it may be mentioned that at a depth of only 50 km. the pressure is in the neighborhood of 15,000 kg. per sq. cm., which is

---

[18] This is defined as the ratio of the lateral stretching to the longitudinal compression under a direct thrust.

already rather beyond the range used in our laboratory compressibility measurements.

In concluding this part of the discussion, I should like to draw attention to one more deduction that can be drawn from earthquake data. It might be supposed that the material of the earth is all of the same nature as at the surface and that the increase of density towards the centre of the earth is due to

TABLE IX.

Velocity of Earthquake Waves and the Elastic Constants of Rocks.

Depth in km.	Velocity* km. per sec.	Velocity† km. per sec.	Poisson's‡ ratio
0	7.4	7.17	0.258
100	7.76	7.59	0.273
200	. . .	8.01	0.272
300	8.57	8.42	0.272
400	. . .	8.83	0.274
500	. . .	9.22	0.272
600	. . .	9.62	0.274
700	. . .	10.00	0.273
800	. . .	10.37	0.272
900	. . .	10.73	0.271
1000	11.24	11.07	0.270
1100	. . .	11.42	0.270
1200	. . .	11.75	0.269
1300	. . .	12.08	0.268
1400	12.06	12.40	. . .
1650	12.53	. . .	. . .
1900	12.80	. . .	. . .
2500	12.95	. . .	. . .

*Calculated by Adams and Williamson from earthquake data of the Dominion Observatory, Canada.

†Calculated at Göttingen by Wiechert and his co-workers from earthquake data.

compression. If this were so we should have another equation connecting the density with the surface density and the compressibility, so that we could now solve the previous problem completely. The actual details of the mathematics are rather burdensome, although no special difficulties are encountered, so I shall merely state here the general result obtained. The supposition mentioned can be proved quite untenable, as the calculated mean density of the earth proves to be much too low. Part of the increase of density is therefore due to the presence of heavier material, as has, of course, always been supposed by a large school of thinkers.

In the closing paragraphs a few words will be said about another fundamental property of liquids, the viscosity. Anyone who has worked at all with pressures knows that this is a property which is affected in the very highest degree by pressure. For instance, in using an ordinary oil pressure pump with a good grade of lubricating oil, almost immediate response to pumping

FIG. 6.
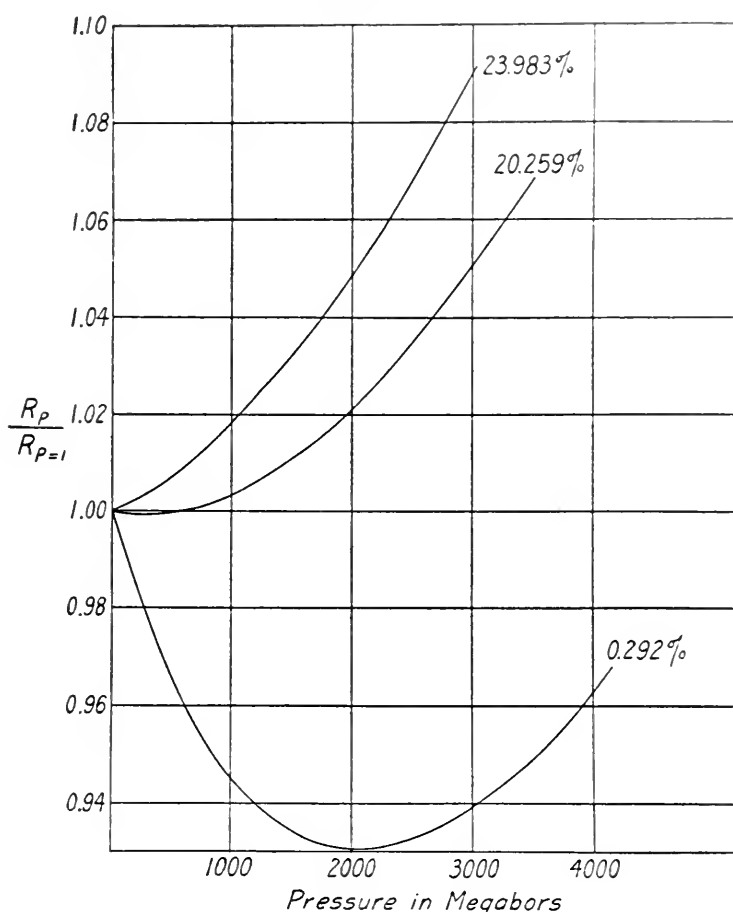
Curves showing the pressure effect on the electrical resistance of solutions. The data are collected in Tables IV, V and VI.

is made by a gauge at a distant part of the apparatus, but at about three or four thousand atmospheres at ordinary temperatures this is no longer so, if even a fairly short length of tube separates the gauge from the pump. Judging by our experiences of this nature, when measuring compressibilities with kerosone as the transmitting fluid, it would seem that at 12,000 atmospheres kerosene is more viscous than vaseline is at the same temperature and zero pressure.

In the case of lubricating oils this change of viscosity with pressure may be of some importance, and several researches have been carried on in regard to it. I quote from a paper by

FIG. 7.
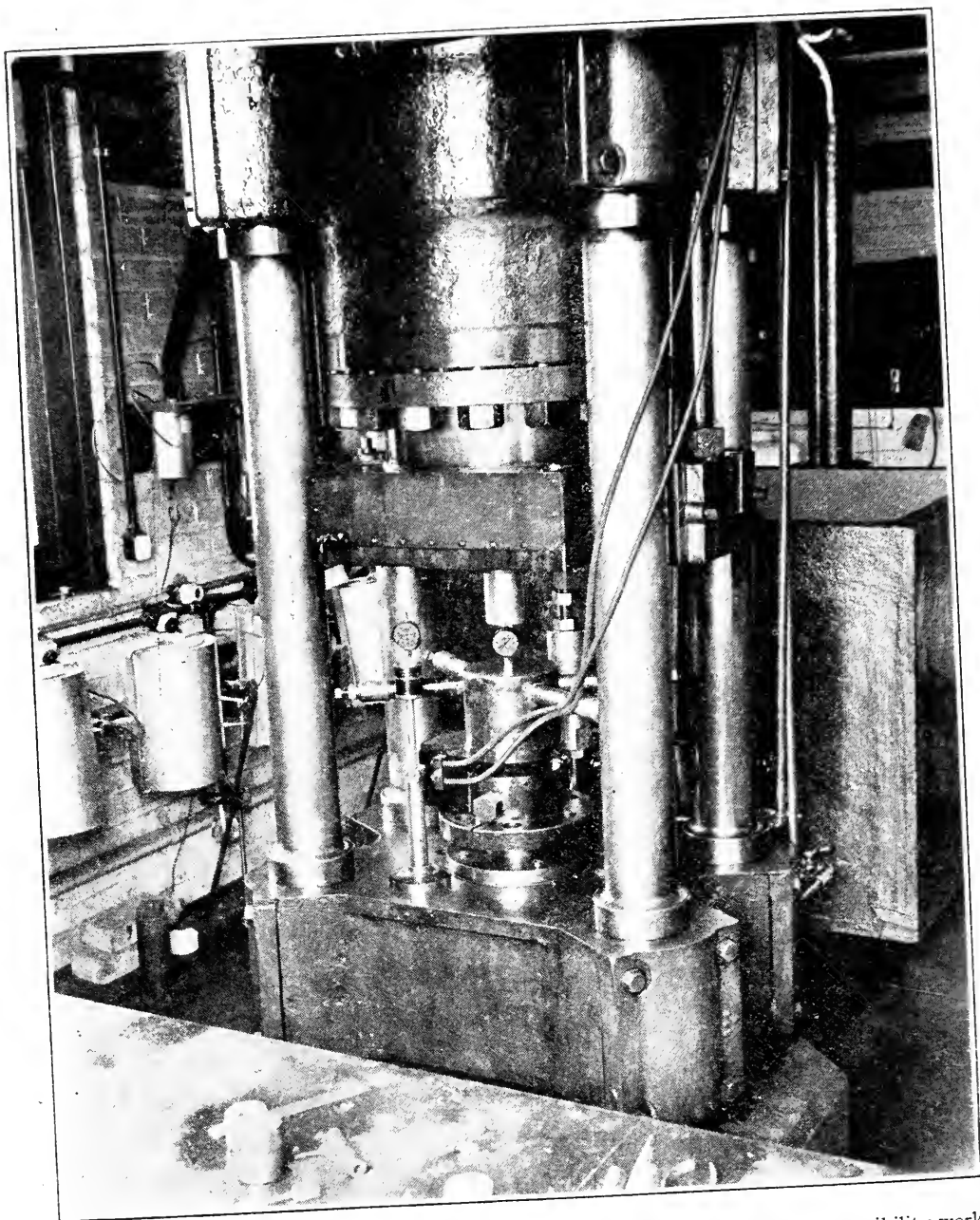
Photograph of hydraulic press with the bomb and connections as used in compressibility work.

J. H. Hyde:[19] "The research here described was undertaken for the Committee on Lubricants and Lubrication of the Depart-

[19] *Proc. Roy. Soc. London,* **97,** 240, 1920.

ment of Scientific and Industrial Research, for the purpose of the analyses of the results of a previous investigation into the efficiency of power transmission through a worm-gear when different kinds of oil, animal, vegetable and mineral, were used as lubricants. Since pressures of the order of five tons per square inch between the lubricated surfaces of worm-gears are not uncommon, a knowledge of the rates of variation of the viscosities of the oils up to these pressures was essential, and as this information was not obtainable, the experiments necessary for the determinations were put in hand at the request of the committee."

TABLE X.

Viscosities of Typical Oils Under Pressure. *

Pressure kg. per sq. cm.	K			
	Victory Red (mineral)	Trotter oil (animal)	Rape oil (vegetable)	Sperm oil (fish)
1	1.00	1.00	1.00	1.00
157.5	1.54	1.20	1.13	1.23
315	2.67	1.60	1.44	1.54
472.5	4.62	2.00	1.88	1.94
630	7.94	2.40	2.35	2.31
787.5	12.26	. . .	2.91	. . .
945	19.58	. . .	. . .	3.14
1102.5	. . .	3.54	3.50	. . .
1260	. . .	5.03	. . .	. . .

*Table by J. H. Hyde, *op. cit.*

Table X and Fig. 8 show a number of the results obtained. K stands for the ratio of the viscosity under pressure to the viscosity at one atmosphere. The maximum value of K found for the range covered is 26.5 for Mobiloil BB under a pressure of 1019 kg. per sq. cm.

Returning now to our own experiences, these have led us to use a good light motor oil (such as Peerless motor spirit) for medium pressures, kerosene in our higher pressure bombs, and petroleum ether when a low temperature is combined with a high pressure. The use of these is possible only in a leak-tight apparatus. If it is necessary to have a small leak, as for instance in using an absolute gauge of the moving piston type, a viscous liquid must be used where the leak is. In a great deal of the older high-pressure work this difficulty greatly diminished the value of the

results, and all credit is due Doctor Bridgman for his pioneer work in the development of leak-proof apparatus.

In conclusion one may say that the work already done on these lines has borne good fruit, and as the initial experimental difficulties have been largely overcome it should be possible in the future to obtain more numerous and more accurate results with a corre-

FIG. 8.
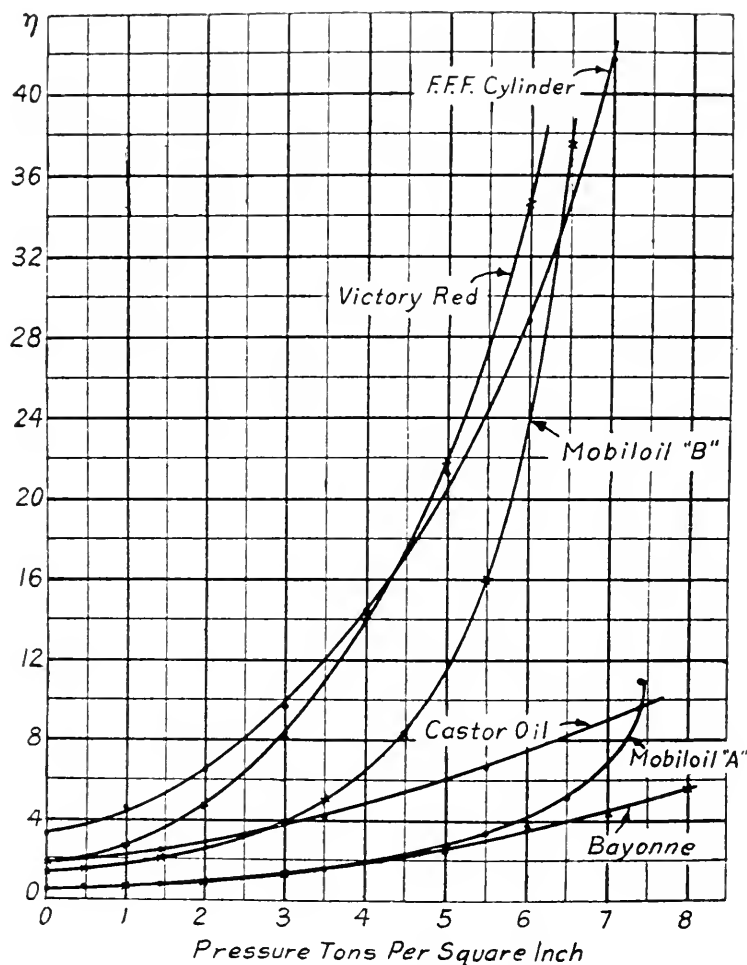
Curves from J. H. Hyde (*op. cit.*) showing the effect of pressure on the viscosity of oils.

sponding increase in their usefulness. The late Professor Tait, in his well-known book on the " Properties of Matter," wrote while dealing with the subject of compressibility : " It is greatly to be desired that more, and more accurate, data should be obtained in this matter—though the problem is one of very great uncertainty as well as difficulty. Difficulty incites rather than repels a true experimenter, but uncertainty is paralyzing." In

the rather less than twenty years which have elapsed since Tait died these uncertainties have been removed, so that while the difficulty remains the paralysis has been permanently cured. With sufficient care and patience a degree of accuracy may be reached which is beyond what he dreamt of, while the range of experimentation has been increased tenfold.

Geophysical Laboratory,
  Carnegie Institution of Washington,
    Washington, D. C.,
      December, 1921.

On Whispering Gallery Phenomena. G. V. Raman and G. A. Sutherland. (*Proc. Royal Society*, A 705.)—The interesting acoustical properties of such structures as the domes of St. Paul's Cathedral and of the Capitol at Washington have for a long time called for scientific explanation. The late Lord Rayleigh regarded the sound-wave as following the concave surface around from their source to the point where they were so distinctly audible. This was supported by using a directed source of sound placed near the curved surface. When this source sent its waves off tangentially to the surface the greatest effect was observed. Furthermore, when a bird-call as sound origin and a sensitive flame as recipient were employed, it was found that a rather small obstacle located near the curved wall shut off most of the effect. The authors experimented with a flexible mirror along which a ray of light took its course and they observed bands of light and darkness. With this optical analog as a guide, they carried out a series of experiments in the dome of St. Paul's. A steady source of sound was maintained at the wall at one point. Then observations were made by ear at various points around the circumference. As the ear was moved radially away from the wall, it was evident that at intervals about equal to the wave-length of the wave sound and comparative silence alternated. " Very pronounced fluctuations of intensity were also noticeable when the observer's head was moved circumferentially; that is, parallel to the wall, and this latter effect, though detectable everywhere, was most marked near the far end of the diameter of the gallery in which the source was situated." Both of the types of fluctuations were confirmed by the impartial sensitive flame. When a semicircular archway was used both the radial and the circumferential variations manifested themselves but with certain differences of character.

  "Rayleigh's theory is attractive in its simplicity, but as is evident from the foregoing experimental results, it does not fully explain the observed phenomena." G. F. S.

The Growth and Decay of Photo-thermionic Currents from Oxide-coated Filaments. H. D. ARNOLD and H. E. IVES. (*Proc. Nat. Acad. Sciences,* Dec., 1921.)—Merritt and Case have shown that the illumination of the oxide-coated filament of an audion is followed by an increase of the current between the filament and the plate. Merritt further showed that the increase was chiefly due to radiation of short wave-length and interpreted the effect as due to an increased emission of electrons from the filament under the excitation of the incident light.

In the present investigation light that had passed through a red glass fell on the filament. The change in space current was recorded by a string galvanometer. It was concluded that the heating effect of the red light is mainly responsible for the changes occurring. When light transmitted by blue glass was used the heating effect was quite small, yet there was still a change in the space current. A study of this, as the heating current in the filament varied, led the authors to believe that some light effect different from the true photo-electric effect is the cause of the phenomenon. There is a similarity in the features of the growth and decay of the current to the variation of selenium in resistance under illumination that justifies the suggestion " that the cause of the light effect in the oxide-coated filament may be closely related to that which gives selenium its photo-sensitive properties."

G. F. S.

Some Problems of the Sea. L. F. FARIS. (*Jour. Washington Acad. Sciences,* March 4, 1922.)—" A problem of much importance in the study of the physics of the earth is the determination of the intensity of gravity at sea first, to furnish further information that will enable us to ascertain more accurately the shape of the earth, and second, to determine the distribution of the densities in the so-called 'isostatic shell' of the lithosphere.

" Researches in this and other countries have made it certain that the outer seventy miles of the earth's material is in a state of approximate isostatic equilibrium. If we assume a surface seventy miles below sea level under the continent and on this surface lay out squares approximately one hundred miles on a side and extend vertical planes from these to the surface of the earth, we should have the same mass in each of the columns, though some of the columns would be a mile or more longer than others. In other words, each column of equal cross-section is found to have about the same pressure on the nucleus at a depth of seventy miles below sea level as any other column. Do these conditions exist under the ocean? The answer to this question requires the obtaining of observations for the intensity of gravity over ocean areas."

G. F. S.

CONTROL OF CORROSION BY DEACTIVATION
OF WATER.*

BY

FRANK N. SPELLER, B.A.Sc., Member A.S.M.E.

Metallurgical Engineer, National Tube Company.

INTRODUCTION.

REPLACEMENTS made necessary due to corrosion of iron and steel in this country have been estimated to run over one million tons per annum. While this is perhaps little better than a guess, it is probably not overstating the facts. Much of this loss occurs in piping, boilers and other closed systems. For example, a large modern building contains over two hundred miles of piping of all kinds. These are the arteries of the structure, which are both difficult and expensive to replace. The hot-water piping is most subject to attack, frequently lasting less than ten years under modern conditions.

One of the most fruitful means for effecting economy is through the elimination of waste. The subject of this paper deals particularly with the conservation of iron and steel in contact with water in closed systems, but it may be well to first outline briefly some of the important facts and principles relating to corrosion in general.

The Electrolytic Theory of Corrosion has been stated in various terms in a number of articles which may be referred to by those who are particularly interested in this phase of the subject.[1] The essential reactions are: The action of hydrogen ions in water which results in the solution of iron; the concentration of hydrogen ions, acidity of solution; the polarization of the metallic surface by deposition of hydrogen which protects the metal from further attack; the retarding effect of ferrous hydrate in solution; and the removal of deposited hydrogen and

---

* Communicated by the Author.

[1] "Corrosion of Steel," A. S. Cushman: J. OF FRANKLIN INST., 165, 111, 1908. "Corrosion of Iron and Steel," W. H. Walker: *J. Am. Chem. Soc.*, 29, 1251; 30, 473, 1907. "Preservation of Hot Water Supply Pipe," Speller and Knowland: *Trans. A. S. of H. and V. Engineers*, vol. 24, 1918.

ferrous hydrate by oxygen in solution in water. Without the last reaction, corrosion cannot proceed to any appreciable extent, except in rare cases where a high hydrogen ion concentration is maintained, as where water contains magnesium chloride. In this case the water when heated brings about the following reaction: $MgCl_2 + 2H_2O = Mg(OH)_2 + 2HCl$. In contact with iron, ferrous chloride is then formed, which is hydrolyzed by water ($FeCl_2 + 2H_2O = Fe(OH)_2 + 2HCl$). These reactions are cyclic and will continue in the presence of free oxygen, which disturbs the equilibrium of the last reaction by formation of insoluble ferric hydrate ($4Fe(OH)_2 + O_2 + 2H_2O = 4Fe(OH)_3$).

In most cases the amount of free oxygen available determines the amount and character of corrosion. It is therefore convenient to divide corrosion of iron into three broad classes:

I. *Atmospheric corrosion,* where oxygen is available in large excess.

II. *Underwater corrosion,* where the amount of oxygen present is limited to the solubility of that gas in water.

III. *Soil corrosion,* in which the ratio of moisture to available oxygen varies considerably but where the influence of contact of the metal with dissimilar materials and different electrolytes is likely to be an important factor in accelerating corrosion. This has no reference to the influence of electrolysis from stray electric currents *per se,* which is another problem[2].

In this paper the author confines the discussion to the second of these three classes, which includes broadly, corrosion of the interior of pipes, tanks, economizers, boilers and other closed water systems which form such an important part of building, and power plant construction. Before discussing the practical solution of this problem, it may be well to refer briefly to the main factors which influence corrosion.

EXTERNAL FACTORS.

The main factors which control the rate and distribution of corrosion of iron in water (and this applies, generally speaking, to brass and some other metals) are given below in order of importance:

(a) Amount of oxygen in solution;

---

[2] Report of Committee on Electrolysis, 1921, *Am. Inst. of Electrical Engrs.*

(b) Temperature;

(c) Quantity and velocity of flow;

(d) Quality of water; presence of one or more electrolytes
     in solution;

(e) Contact with electro-negative material.

Irregular corrosion, known as pitting, is brought about by contact of the metal with electro-negative materials such as mill scale, brass, copper, but in the absence of free oxygen the influence of all other factors mentioned is insignificant, except where acid is generated continuously, in which case there will be some solution of iron but much less where free oxygen is not present.

COMPOSITION OF MATERIAL.

Before discussing what has been done and what may still be accomplished to conserve such material, it is in order perhaps to answer the question: What may be expected from special treatment of the metal, or what has been done towards the production of a non-corrosive metal suitable for such conditions? A large amount of thought and work has been devoted to this field by metallurgists with some results of note in the manufacture of special alloys such as monel metal, dur-iron, stellite, stainless steel (high-chrome steel), and other alloys, all of which, due to their non-rusting qualities, have useful fields. However, the use of these alloys is unfortunately limited by their high cost and the fact that such metals have not as yet been successfully fabricated for general purposes. So that we must still use such well-known material as zinc, tinplate, brass, copper, wrought iron and steel (uncoated or galvanized) and for most purposes for economic reasons, the choice is usually confined to the last two mentioned. Steel carrying 0.25 per cent. copper has proved much better than non-copper bearing steel under atmospheric corrosion, but unfortunately has shown no superiority underwater or underground.

RELATIVE RATE OF CORROSION.

In passing, it may be useful to refer to a few of the many comparative tests of wrought iron and steel in water lines which have been made in recent years, for opinions are still somewhat divided in certain quarters on this question.

The author has previously summarized some of the practical information from experience and tests in service on wrought iron

and steel pipe in a paper before the International Association for Testing Materials—1912. Since that time considerable data have been collected from various sources which are summarized in Table I. An extensive series of tests in acid mine water was reported on by Committee A5—A.S.T.M., 1921[3]. The conclusion reached is practically the same from all these investigations, *viz.*, that under water the origin and composition of iron makes comparatively little difference in the rate or character of corrosion. Whatever the influence of composition may be it is apparently small compared with the marked influence of variations in surface finish of the metal, internal strain, contact with other materials which are relatively more electro-negative in character, to say nothing of the predominating influence of other external factors referred to above which, after all, have most to do with controlling the rate of corrosion. Enough has been said to indicate that at present in many cases, we have no choice but to consider means for keeping the water from contact with the metal or to remove the corrosive power of water and thereby render it inactive. Thus corrosion may be prevented or greatly retarded either by means of protective coatings or by removing the free oxygen from water.

PROTECTIVE COATINGS.

Many protective coatings have been devised to protect pipes and other metallic structures under water. These may be divided into (a) non-metallic coatings such as paints and bituminous dips, (b) metallic coatings. The latter may be classified into metallic coatings which are electro-negative to iron and those which are electro-positive. The former include lead, tin, copper, nickel, and protect only so long as the coating is intact, after which the coating metal usually accelerates corrosion and results in pitting. Electro-positive metals include such as zinc, aluminum and certain kinds of brass. Iron is protected by such metals, even though the protective coating does not entirely cover the surface, until the area of iron exposed becomes so large as to extend outside the range of galvanic influence of the more electro-positive metal. Zinc coatings on account of their economy and ease of application are most generally used and find a wide and useful application in various forms such as hot galvanizing, electro-

---

[3] *Proc. A. S. T. M.,* vol. 21, p. 157, 1921.

galvanizing, Sherardizing and spraying. Each of these methods of zinc coating has special advantages for certain purposes which have been developed by experience.[4]

There is good evidence that iron and steel acquire under certain conditions a protective film or scale which often has considerable influence in warding off the attack of hydrogen ions in water. Iron or steel which contains over 0.10 per cent. copper has a very decided tendency to develop a strongly adhering and more or less impervious coating of rust *under atmospheric corrosion,* but under water this metal corrodes like non-copper bearing steel, evidently because the rust formed under these conditions does not adhere so well and is more open in its physical structure. Steam pipes which have been in use for many years often exhibit such coatings, particularly where the steam carries a small amount of oil, which results in a protective coating consisting of a mixture of hydroxides of iron and certain oily deposits. The absence of this coating in modern systems fed by steam generated and delivered directly for heating purposes has in some cases resulted in more corrosion than where exhaust steam was previously used. The remedy for this is to reduce the free oxygen and carbonic acid in the boiler make-up water to a minimum, and keep the system tight as far as possible.

Waters of certain compositions throw down a protective deposit of organic or inorganic material on the inside surface of pipe, which has a marked effect in retarding corrosion. It has been observed that some of the domestic waters of New England are more corrosive since filtration has come into more general use.

Another instance of natural scale forming is found where water from the Great Lakes is heated for domestic use or power purposes. A thin scale is usually found on the inside of pipes which carry this water; the average of several analyses of such scales collected by the author gave:

Iron .... 28.4 per cent.
Lime, CaCO₃ .... 3.0 per cent.
Silica .... 4.8 per cent.

The lime and magnesia are usually present as bicarbonates in

---

[4] Bureau of Standards Circular No. 80, " Protective Metallic Coatings for Rust-proofing of Iron and Steel." October, 1919.

these waters, and when heated a portion of the half-bound CO_2 is removed, resulting in precipitation of some of the lime. The silica found in these scales is probably precipitated by reaction with colloid ferric hydrate which always forms a large proportion of these scales. The study which the writer has made of pipe corrosion with various domestic waters has shown that there is a marked difference in the life of pipe in certain localities—one of the most noticeable contrasts in this respect is between the rate of corrosion of pipe used in the Great Lake cities where a comparatively hard scale-forming water is used, in comparison with the action of domestic water of New York or New England, which is relatively purer and softer. Generally speaking, hot-water pipes under the former conditions last two or three times as long as in the latter, other factors being the same.

It is quite possible that some practical means will be developed to give domestic water this scale-forming property without making it objectionable in other respects. Some research work on this problem has been under way for a year or so in our laboratory, which indicates that while such protection is incomplete compared with deactivation of water, that it is possible to form a coating on the inside of pipes under certain conditions, which will cut down corrosion sufficiently to prevent all but a slight discoloration of the water.

DISSOLVED OXYGEN IN WATER.

The controlling influence of free oxygen on corrosion in water is clearly indicated by the electrolytic theory and has been repeatedly demonstrated by experiments and confirmed by practical experience (Fig. 3). The solubility of oxygen in pure water follows the Law of Henry, which states that the solubility of a gas at a given temperature is proportional to the pressure of the gas above the solution. Expressed as a vapor pressure law, this means that the partial pressure of a volatile solute from a solution is proportional to its molecular fraction or to its concentration.

The solubility of oxygen in salt and fresh water at atmospheric pressure varies with the temperature as indicated in the chart (Fig. 1).

The chart shown in Fig. 2 was prepared by Mr. T. M. Knowland for a report for the National Tube Company from

work in the Massachusetts Institute of Technology Research Laboratory and will be found useful for calculating the amount of oxygen dissolved in water from air at any temperature or pressure.

The solubility of iron in water is usually so low that in the absence of oxygen, corrosion is negligible except, as we have pointed out before, where the concentration of H ions is considerable and is maintained by some means, in which case such corrosion cannot be ignored. However, this condition is rarely found in domestic water and but occasionally in water used for

FIG. 1.

Solubility of Oxygen in Water at 760 M.M.
(from air saturated with water vapor)

Saturation Curve – Fresh Water
Saturation Curve – Sea Water
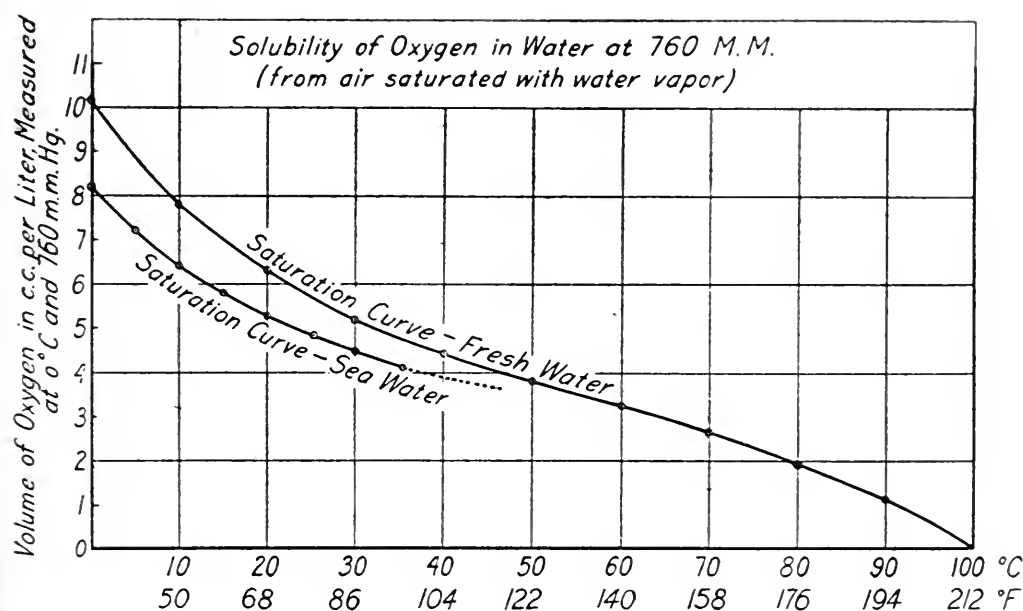
power purposes. In these cases the acid or acid-forming compound, which is usually magnesium chloride, may be neutralized by the addition of lime.

Fig. 3 shows in diagramatic form results of a series of weighed tests of corrosion in water, made under constant conditions but with varying oxygen contents. The water was passed continuously through a series of steel cylinders (Fig. 4), in which were placed varying amounts of perforated steel sheets so that the oxygen content of the water was reduced by stages.

The problem of protection of metal pipes or tanks carrying water is therefore one of removing the free oxygen from the water before it enters the system and preventing further supply of oxygen. To secure practical immunity from attack, it is not

necessary to remove all the free oxygen; the amount which may
be tolerated depends on the temperature and amount of water
passing through the system. For example, a hot-water service
system for a building where water is used at 135° will show no
serious corrosion with an oxygen content of 1.0 c.c. per litre;
at 170° F., to get as good results, the oxygen contents should not
be over one-half of this, or 0.5 c.c. per litre; and in the case of
a boiler economizer operating at 300° F., the residual oxygen
would probably have to be reduced to 0.2 c.c. per litre to reduce

FIG. 2.
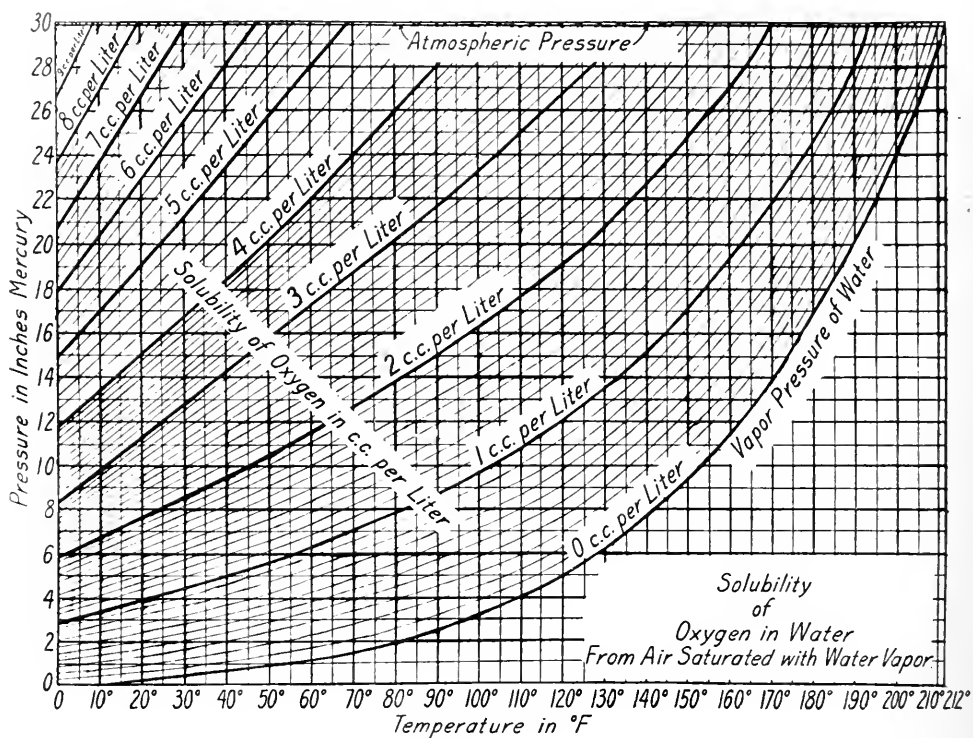
corrosion to a negligible amount. There are other factors, of
course, which make this estimate only approximate, but as it is
a more difficult and costly matter to remove the last one-half c.c.
of oxygen per litre from water, the degree of removal required
is one of the main considerations in determining the selection of
the most suitable and economical apparatus for any particular case.

Oxygen removal apparatus has been developed to a high
degree of efficiency in this country during the past six years as a
result of various designs which have been worked out in service.

These may be divided into three classes, according to the
principles employed:

1. Apparatus for oxygen removal by chemical means.
2. For oxygen removal by mechanical or physical means.
3. Combinations of the above in the same plant.

OXYGEN REMOVAL BY CHEMICAL MEANS (DEACTIVATION OF WATER) IN THE UNITED STATES.

We have frequently noticed that in service more corrosion is found near the inlet to a pipe system than farther away; that in boilers there is more corrosion near the feed-water entrance;

FIG. 3.

Showing Corrosion of Steel Test Pieces in Waters Carrying Different Oxygen Contents. Test Covering Period of 150 Days. Temperature of Water 160°F.

Dissolved Oxygen in Water – c.c. per Liter

Loss in Weight of Test Pieces – Grams
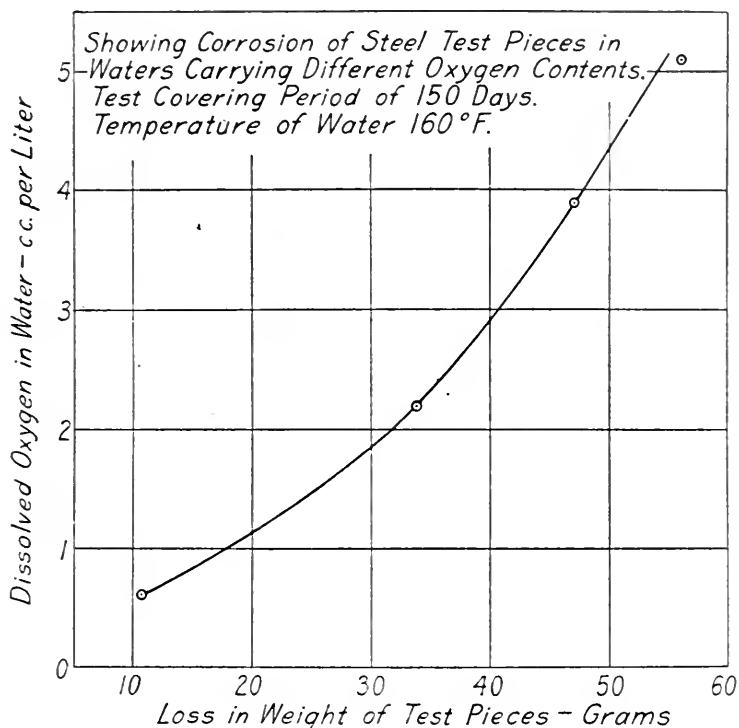
and that in hot-water *heating* systems where only a relatively small amount of water is added each season, no serious damage occurs. Such experience and the viewpoint of corrosion given by the electrolytic theory, led the author to experiment in 1906 with the removal of free oxygen from water by means of contact with a large surface of scrap iron for which apparatus was built in the Research Laboratory of the National Tube Company. Favorable results were obtained, but continuous operation of such a plant over a long period of time required considerable experimental work on a working scale, and it was not until 1915 that

a satisfactory plant constructed on this principle was put into working operation in a building in Pittsburgh.[5]

For lack of a distinctive name, the word " deactivator " was adopted to describe such an apparatus, for water after having

FIG. 4.
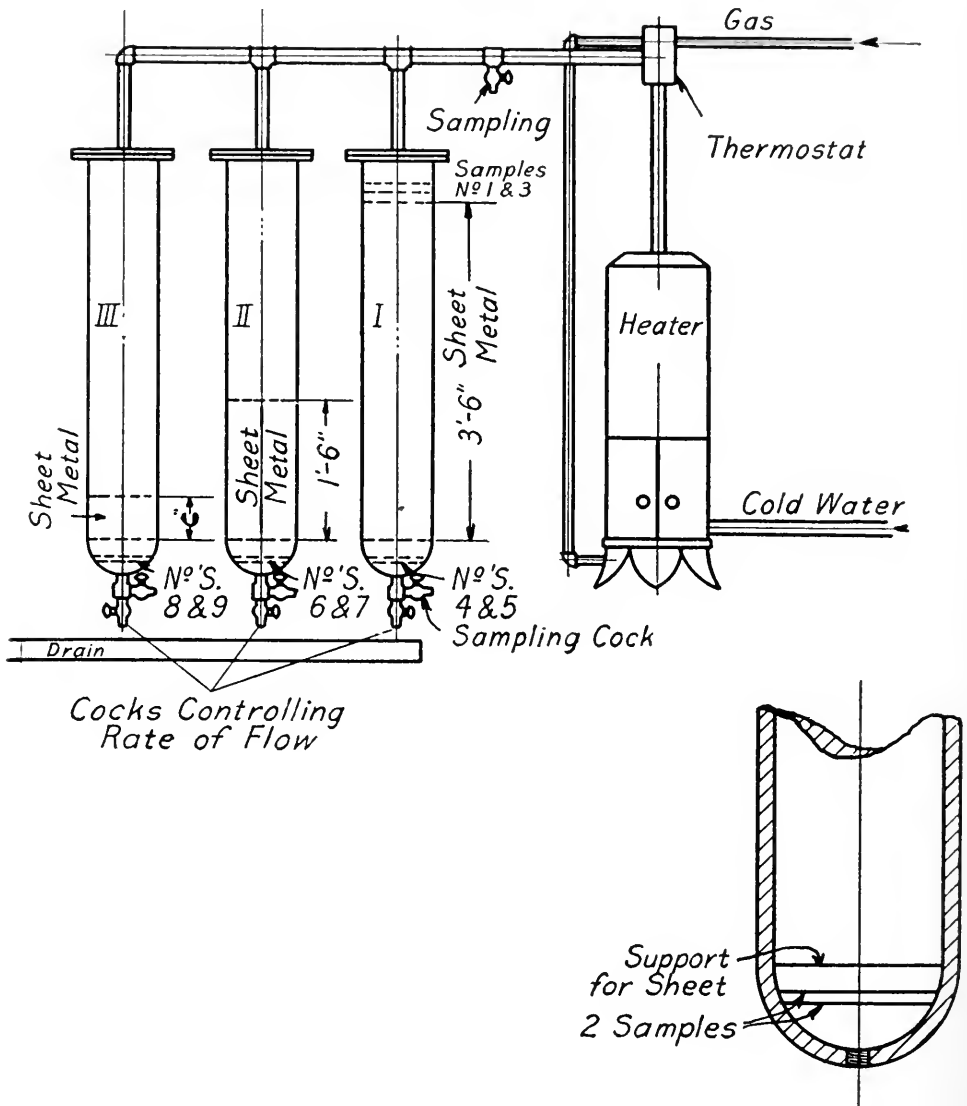
Space occupied by sheet metal (26 gage). Tank No. 1, 33,500 c.c; No. 2, 14,366 c.c; No. 3, 4790 c.c.

most of its dissolved oxygen removed in this way, has been found to be *inactive* toward iron. The deactivating tank is preferably filled with a special type of expanded steel lathing (about

[5] Described by the Author as " A Method for Practical Elimination of Corrosion in Hot Water Supply Pipe." *Proc. A. S. H. and V. Engineers,* vol. **23**, 125. 1917.

26-gage), so formed that the individual sheets will not lay so close as to cause excessive resistance to flow. Miscellaneous steel turnings usually rust together in a tight mass in time so as to seriously interfere with flow. Figs. 5 and 6 show the influence of varying temperature on deactivation. The density of the steel, as expressed in square feet of surface per cubic foot of volume, is another important factor affecting the rate of oxygen removal by this method.[6]

A later form of deactivator installed in an apartment in Boston in 1917 is shown in Fig. 7. A filter was provided in order to

FIG. 5.

Showing Oxygen Removed at Different Temperatures.
Initial Oxygen Content of Water—7.5 c.c. per Liter
Tests Made in Deactivator
Time of Contact with Iron—45 Minutes
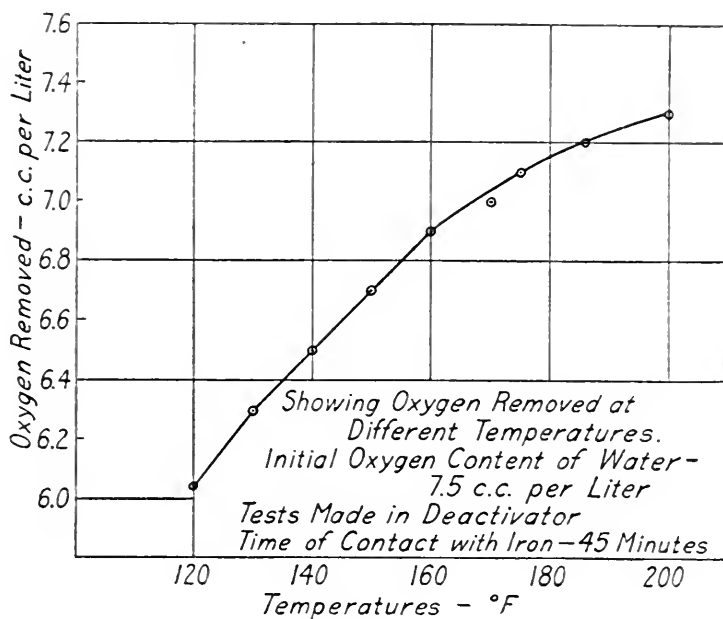
secure clear water free from iron hydroxide; the iron found in solution in the filtered deactivated water is usually less than 0.2 p.p.m. Experiments conducted by Dr. W. H. Walker and his associates at the Massachusetts Institute of Technology, Industrial Research Department, on coagulation of iron in deactivated water, developed the fact that by rendering the water slightly alkaline to phenolphthalein, the colloidal iron could be readily coagulated, and that passing water through a slightly soluble form of granular magnesium oxide was a very convenient means for accomplishing this result. This gave a simple and automatic

[6] U. S. Patents No. 900,323, No. 1,204,602, No. 1,274,099 (F. N. Speller) refer to the application of this principle to the removal of free oxygen from water.

control of coagulation, which materially increased the efficiency of the filter. This experience suggested to the author the possibility of flocculating the hydroxides of iron to such an extent that they would be retained on the expanded sheet steel of the deactivating tank. Experimental work on the influence of temperature, rate of flow, and alkalinity on the production of clear deactivated water, showed that with a certain relation between these factors good results could be accomplished. The most favorable conditions under which clear deactivated water can

FIG. 6.

Showing Oxygen Removed at Different Temperatures.
Initial Oxygen Content of Water – 1.26 c.c. per Liter.
Tests Made in ¾" Steel Pipe.
Time of Contact in Pipe – 2½ min.
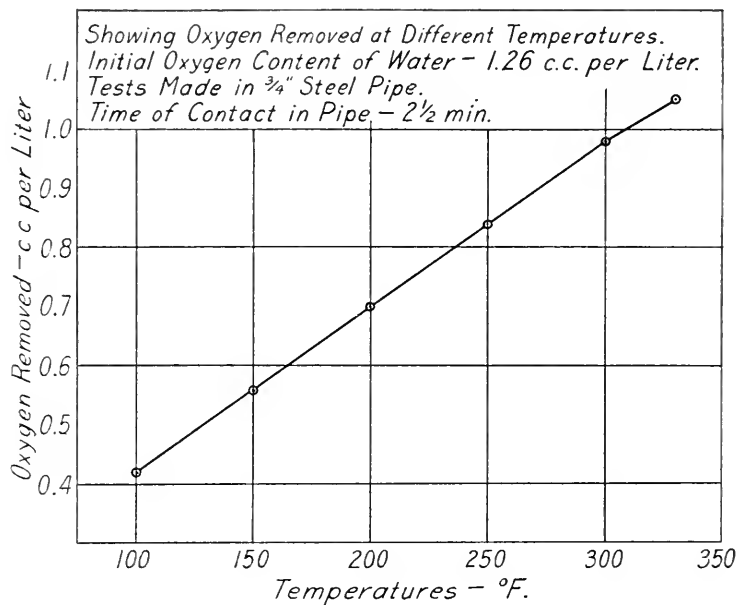
be obtained in service without the use of a filter have been developed by tests on plants in operation, including the one shown in Fig. 7, which now operates without the filter. Fig. 8 shows the latest form of apparatus for this service in which the filter may be omitted or by-passed as desired.[7] However, the rate of consumption of hot water in some buildings is so variable that a filter may be necessary in some cases in order to secure perfectly clear water at all times.

EUROPEAN PRACTICE.

Another form of apparatus for removing dissolved oxygen by use of steel scrap has recently been brought out by Kestner and Paris in Europe and is described in a paper by G. Paris.[8]

[7] Designed by the Anti-Corrosion Engineering Co. of New York.
[8] "Les Corrosions Du Fer et ieur Suppression par le Dégazage de L'eau," *Chimie et Industrie,* vol. 6, No. 1, July, 1921.

The novel feature claimed for this is intermittent and reversible flow, based on the assumption that ferric hydroxide is reduced to the ferrous form when allowed to stand in contact with iron and water for some time. Under these conditions the iron hydrates lose their reddish color to some degree, but we have not found them to be more active in this form even after the deactivator has been allowed to stand at rest for 30 hours. Moreover, most of the plants constructed in this country have operated with periods of rest of at least several hours each day with no perceptible regenerating influence, so that while we have found a slow falling off in activity, the deactivator has been

FIG. 7.
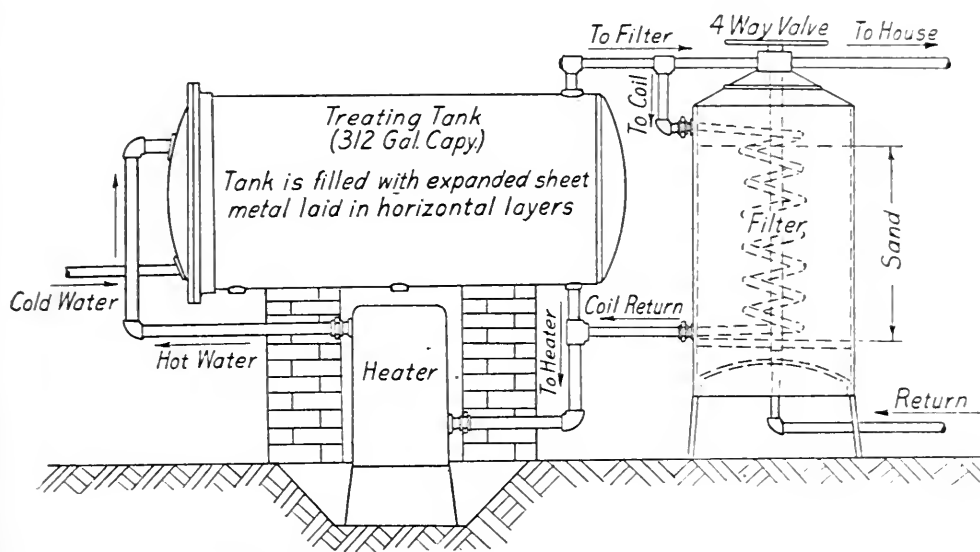
Water heater and deactivator for apartments in Boston.

found to function for as long as four years without renewal with satisfactory results. The author is inclined to believe that the change in color of ferric hydroxide from red to black on standing is due to dehydration rather than to reduction to the ferrous form. However, in this connection, attention should be called to the fact that freshly precipitated ferrous hydrate removes dissolved oxygen from water with great rapidity compared with iron; for instance, Mr. R. G. Knowland, in our research laboratory in 1918, found that freshly precipitated ferrous hydrate combines with all the oxygen in water at $160°$ F. in a few seconds, whereas steel sheets packed with surface density of 70 square feet per cubic foot of space required at least 40 minutes' contact to

remove 80 per cent. of the oxygen at this temperature. The advantage of the steel sheet method, however, is that it is entirely automatic and will operate for two years or more in a properly proportioned plant without more than casual attention by unskilled help.

A type of deactivator very similar to some of those which

FIG. 8.
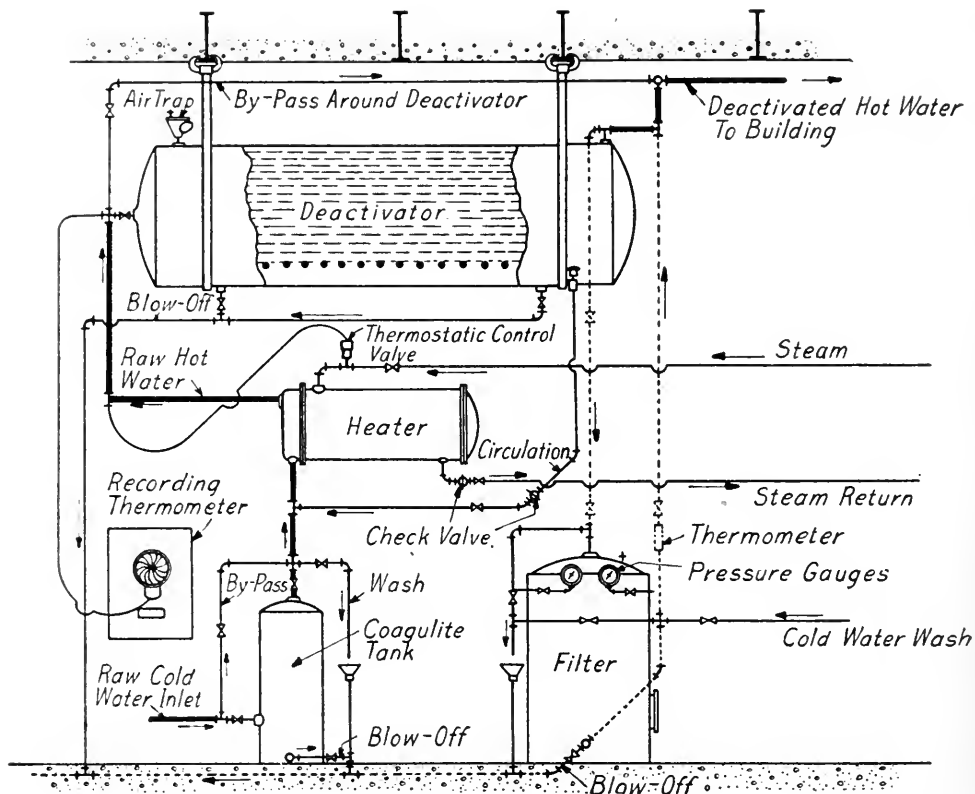
Hot water deactivator. Heavy lines indicate course of water when not using filter.] Light lines indicate by-passes and other necessary connections.

are in operation in this country has been brought out recently by the Metropolitan-Vickers Electric Company of England and another by Hulsmeyer in Germany for power plant purposes, but so far as the records go, none of these have been put to more than very limited use as yet.[9]

RESULTS OF REMOVAL OF OXYGEN BY IRON IN SERVICE.

Twenty or more of such plants have been put into operation to protect the hot-water piping systems of large buildings in the United States during the past two years. There is no practical

[9] *Ibid.*

difficulty that has not been overcome in operating such plants. The residual oxygen may vary from zero to about .75 c.c. per litre during certain parts of the day without doing perceptible damage. It is more difficult to remove the last traces of oxygen which in any case have a negligible influence from a practical standpoint, but when the rate of flow slows down, the oxygen is more completely removed and a large volume of deactivated water is thus

Fig. 9.

Raw water.

Deactivated water.

Two-inch wrought iron pipe in service two years in the same building.

available for use at any time. So far, experience indicates that the metal should be removed from the deactivating tank every two or three years, depending on the demands of the system. That which has been only partially consumed may be cleaned and put back with new sheets. Domestic water carries on the average for the year 10 p.p.m. of oxygen by weight which will consume about 0.2 pounds of iron per 1000 gallons, which represents a saving of that much iron in useful form in the more inaccessible

parts of the plant. Fig. 9 illustrates the difference between two pieces of the same pipe after three years' service with natural and deactivated water.

DEAERATION BY MECHANICAL MEANS.

Experimental work on oxygen removal at low pressure and high temperatures with which the author has been associated, usually gave an oxygen content lower than the theoretical figure, due to corrosion of the apparatus. With sufficient time and where the water is broken up by spraying or passing over baffles, the theoretical minimum oxygen can always be obtained. Many tests in service have indicated that most of the common types of open feed water heaters when properly vented and operated without excessive load will give approximately the theoretical minimum of oxygen as indicated in saturation curves (Fig. 1).[10]

It is a comparatively easy matter to remove 80 per cent. of the dissolved gases by mechanical means but very difficult to remove the last 5 per cent., so that, as in the case of chemical deactivation, before designing a plant it is important to determine what amount of residual oxygen will be harmful under stated conditions. This depends on the temperature, volume of water handled, and other factors, and must be estimated for any particular set of conditions before undertaking the design of deaerating equipment. The deaerating efficiency desired will evidently have much to do with determining the most economical form of apparatus to use. A few types which have been developed and tried out will be described briefly.

DEAERATION OF HOT WATER.

A simplified form of deaerator, developed by the Anti-Corrosion Engineering Company of New York, is shown in Fig. 10. This operates at atmospheric pressure and consists of three essential parts which may be combined in one shell as indicated in Fig. 10. These are: A heater, heat exchanger, and deaerating chamber. An ingenious method of temperature control is provided which is desirable for efficient operation so that the temperature will not vary more than 3 or 4 degrees from 208° F. at any time.

---

[10] The Author is indebted to Mr. G. H. Gibson of the H. S. B. W.-Cochrane Corporation, Philadelphia, Pa., for considerable data on this point which were obtained from heaters in operation.

FIG. 10.
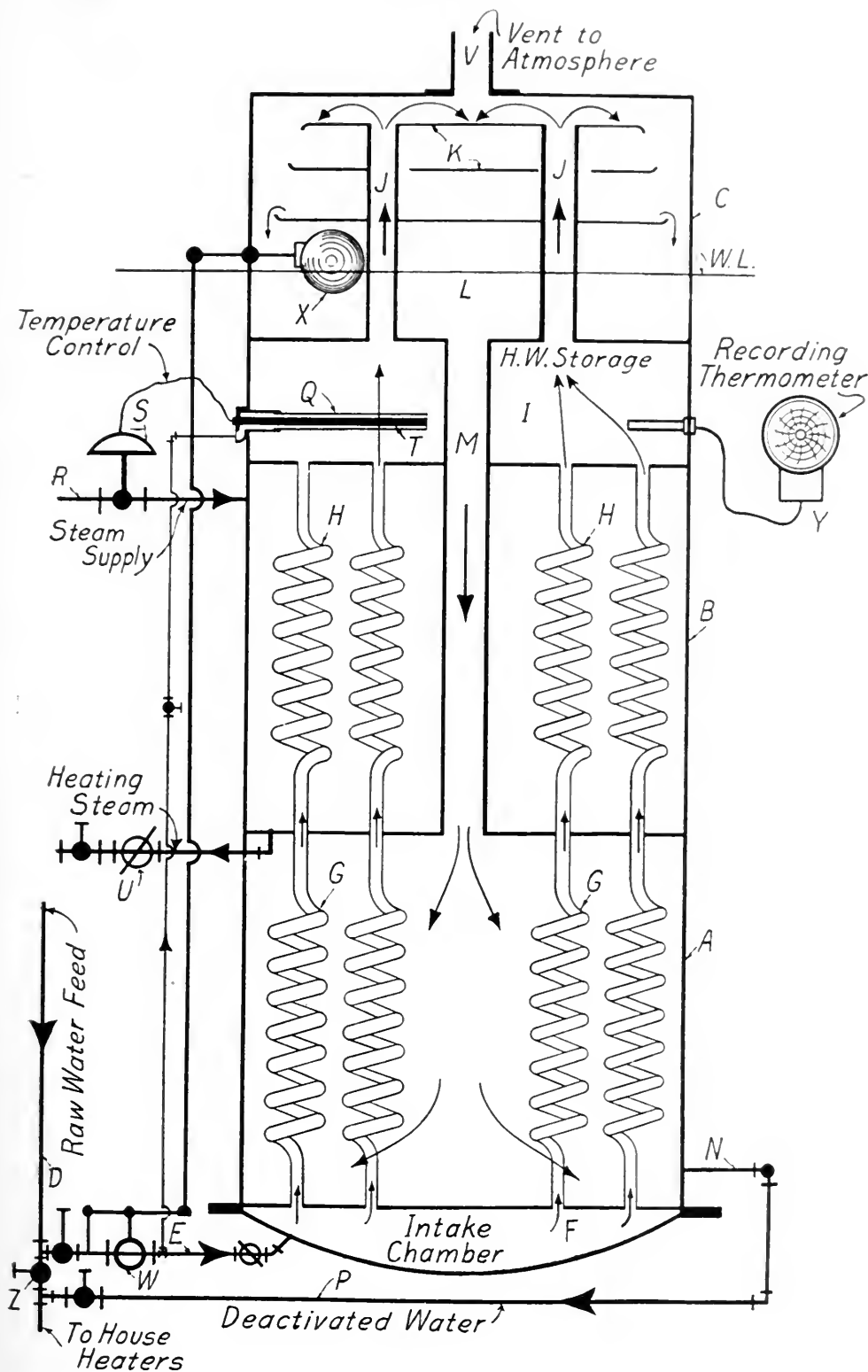
Deaerator operating at atmospheric pressure.

The cold water entering at the point shown near the bottom of the apparatus is partially heated in passing up through the tubes of the heat exchanger by the warmer water coming down. After leaving the heating section, the temperature of the water will be about 208° F. After passing over baffles of the vented deaerating chamber at this temperature, the oxygen contents are found to be reduced to about 0.4 c.c. per litre, which may be still further reduced by passing through zinc scrap or other deactivating material if desired. Usually, however, this is not necessary.

Several of these plants have been installed in large buildings and appear to be fulfilling their purpose in a satisfactory manner. This method of removing free oxygen has been designed from experience in high buildings which obtain their water pressure from open stand-pipes placed at a high level. The same scheme has been adapted to cases where the hot water is repumped and recirculated as in the plant installed for the Girard Estate Passyunk Power Plant, Philadelphia, Pennsylvania. This plant was described by Robert Hughes, Chief Engineer of the Girard Estate.[11] It includes a hot-water service system for 500 houses to which the water is pumped through a four-inch wrought pipe with a three-inch return loop. The piping was so badly damaged and clogged by corrosion after ten years that it was decided to try deaeration. A plant was installed in 1920, on the principle of that shown in Fig. 10, except that the heater was independent of the deaerator and heat exchange units. This plant is illustrated diagrammatically (Fig. 11). The temperature is kept within a range of 194° to 210°, the oxygen being thereby reduced to a maximum of 0.5 c.c. per litre. They report that corrosion has been brought under complete control and the old rust and scale in the piping removed to a large extent. The removal of the hard rust after the oxygen contents of hot water have been reduced at about 0.5 c.c. per litre is a very interesting and unforeseen development which was observed in the first deactivating plant installed by the author in 1915. The disintegration of this old rust is perhaps due to dehydration or may also be due to a reduction of some of the ferric hydroxide to a lower hydroxide which is more soluble.

Another type of mechanical deaerator has been designed and

[11] *Journal Am. Soc. H. and V. Engrs.,* March, 1921. p. 107.

FIG. II.
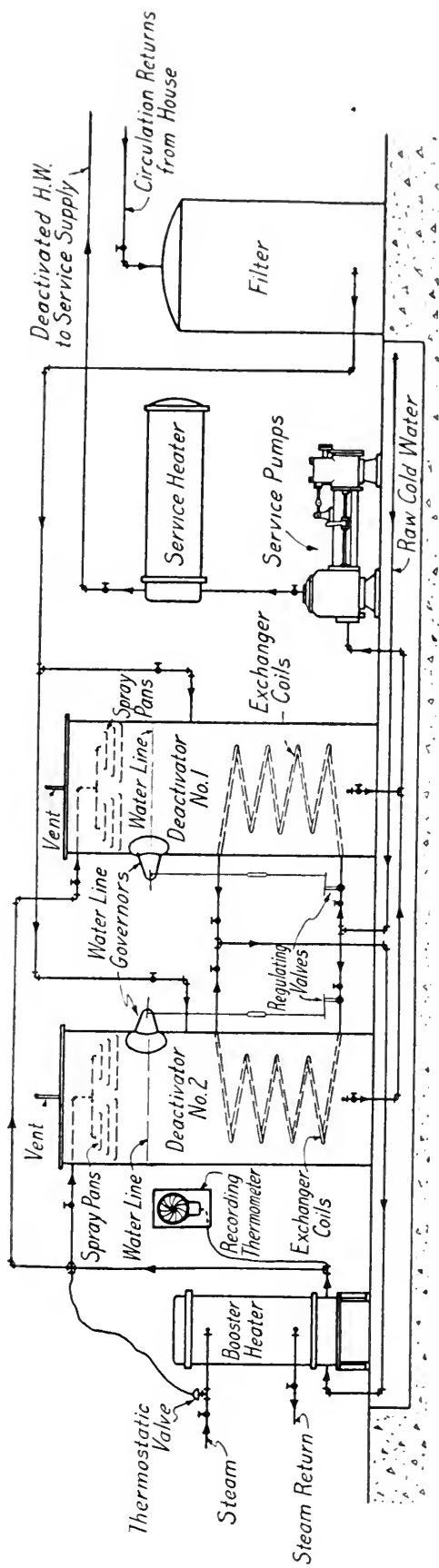
Deactivators—Passyunk Central Heating Plant, Philadelphia, Pa.
(Designed by Anti-Corrosion Engineering Co.)

built by W. S. Elliott, one form of which for large buildings is illustrated (Fig. 12) which operates as follows: Raw water is taken from the supply line and conducted through the cooling circuit of the main surface condenser, which is designated

FIG. 12.
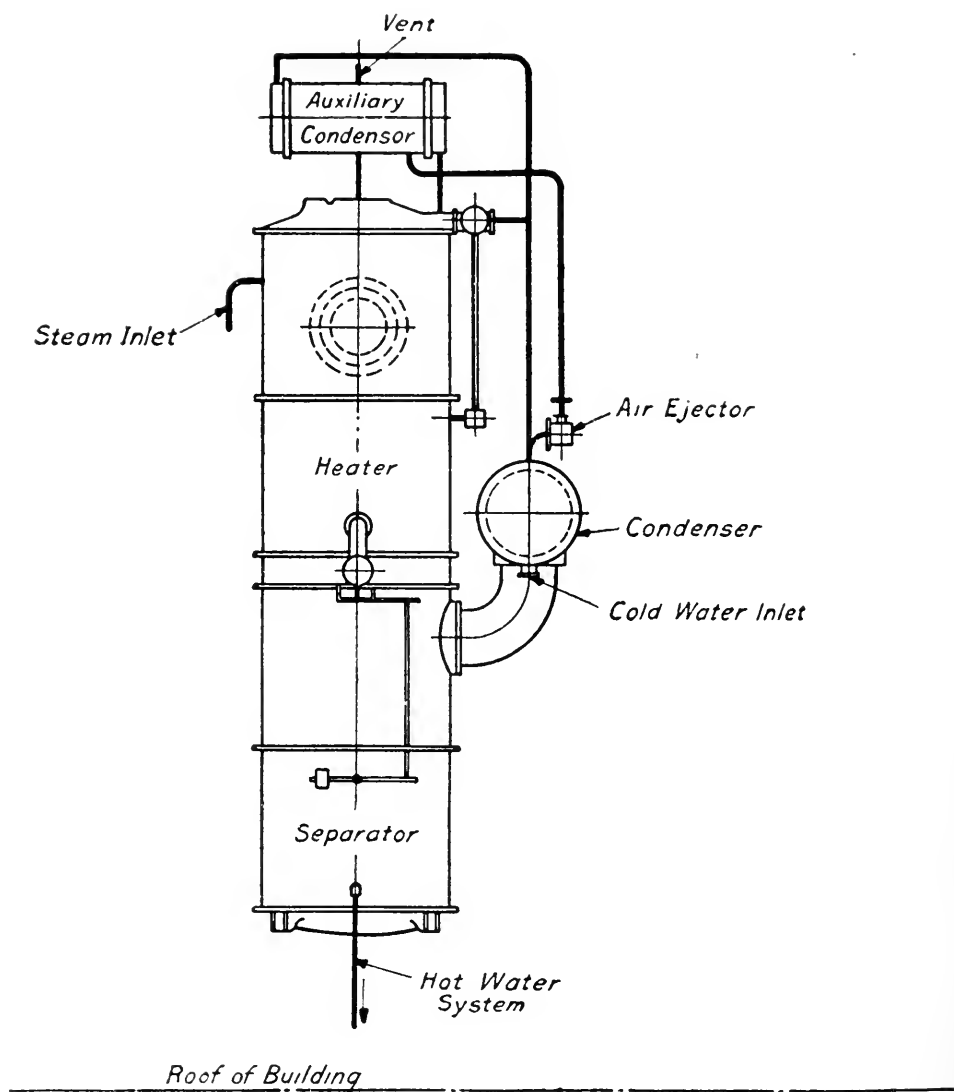
Deaerator operating at reduced pressure.

in the diagram as "condenser." From the surface condenser the water passes to the heater, the flow of the greater portion of it being controlled by the inlet valve of the heater. A small portion of the water is by-passed to the heater through the cooling circuit of a small surface condenser, designated as an "auxiliary con-

denser," the function of which is to condense the steam used in the air ejector and recover the heat.

From the heater the water flows by gravity to the separator, the rate of flow being controlled by the inlet valve of the separator. In the separator, the air is removed by suddenly introducing the heated water into a region of vacuum in which the vapor pressure corresponding to the vacuum is lower than that corresponding to the temperature of the entering water. The water boils explosively, its temperature is lowered to the temperature of the vacuum and the dissolved gases separated. Some portion of the water is evaporated into steam in the separation process and the rest of it flows into the service pump line. The portion which has flashed into steam, mixed with the separated gases, is drawn into the surface condenser which is attached to the separator shell where the steam is condensed and the condensate returned to the separator; the heat of the steam is returned to the cooling water, and the non-condensable gases are removed by steam jet air ejector. From the separator, the hot deaerated water is delivered to the hot-water service line.

When correctly designed and operated at the proper rate, it is reported that very low oxygen contents can be obtained with this apparatus. It would seem that this form of deaerator is one that would be best adapted for large power plant work, for instance where it is necessary to keep the oxygen contents of large quantities of feed water below 0.2 c.c. to preserve steel economizers. One has been installed quite recently in the Delaware plant of the Philadelphia Electric Company.

DEAERATION OF COLD WATER.

Water at normal temperature usually has a comparatively low rate of corrosion and does no serious damage to galvanized pipes within 20 or 30 years, but there are exceptional locations where the cold water is more active or where the corrosion which does occur causes considerable inconvenience through clogging of the system with a bulky form of rust.

Then again cold salt water is more active than fresh water and causes considerable damage in the seaside hotels, bath houses, and in large condensing plants. Such corrosion can usually be reduced to a negligible amount by deaeration. The process of deactivation by steel scrap is usually too slow and therefore not economical for water at normal temperature, so that for such

conditions we are forced to use a high vacuum apparatus. By reference to the diagram, Fig. 2, it will be seen that with a vacuum of 23 inches of mercury, about 80 per cent. oxygen removal may be accomplished with water at 65° F., which is as much as should be needed; in fact, a much lower percentage deaeration would, no doubt, suffice in most cases.

Incidentally it may be of interest to note that deaeration has been usefully applied to cyanide solutions used in the extraction of gold. In 1916 Thomas B. Crowe patented a " Process of, and Apparatus for, Precipitating Materials from Solution " (U. S. Patent Nos. 1,281,249 and 1,321,985), in which the essential element is the deaerating of the gold cyanide solution by means of a vacuum deaerator before the solution is treated with zinc for the precipitation of the gold. Removal of the dissolved oxygen from the solution prevents the formation of zinc oxide, which is said to save about 50 per cent. of the zinc and cyanide formerly used. The Crowe Process, as it is now called, was first installed at the Portland Mill at Colorado Springs, Colorado, but has since been put in use at other mills in the United States and abroad. The chemical reaction taking place in precipitating the gold may be represented as follows:

$$KAu(Cn)_2 + Zn + H_2O = Zn(Cn)_2 + Au + H + KOH.$$
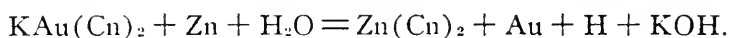
When dissolved oxygen is present, it has been found that zinc oxide is formed and that considerable excess KCn is required to completely precipitate the gold.

Deaeration for prevention of corrosion of a 30-inch steel main at a maximum temperature of 85° F. has been successfully applied on a large scale in the Coolgardie Mining District, Western Australia.[12] This water, which is highly corrosive, is sprayed into a chamber under high vacuum. After operating for a few years, the results show that the deaerator extracts about 80 per cent. of the dissolved oxygen and the corrosion activity is reduced by this means to about one-quarter of the original amount. The residual oxygen is removed after passing through about 30 miles of this pipe, after which the corrosion is reported to be negligible from observations made on steel test pieces. This water carries a small amount of magnesium chloride, otherwise corrosion would, no doubt, be still further reduced by deaeration.

---

[12] A description of this apparatus is found on pages 83 and 84 of a paper by O'Brien and Parr on " The Coolgardie Water Supply." *Inst. of C. E.,* vol. 205, Session 1917–1918, Part I.

EUROPEAN PRACTICE IN MECHANICAL DEAERATION.

Mr. G. Paris, in his paper on "Corrosion of Iron and Its Suppression by the Degasifying of Water,"[13] gives the most complete account which has yet been published of work which has been done on this problem in Europe, most of the practical end of which has been done during the past few years. He points out the drawback of degasification under high vacuum due to the difficulty of holding the vacuum in apparatus of a large size and that the minimum oxygen content is limited by the saturation point of water for any particular temperature and pressure. Evidently his experience has not been so favorable as we have found with apparatus of this class.

Several types of open feed water heaters, and deaerating apparatus, are described for extracting excess gas from water under pressure, with some new devices for separating gases mechanically from hot water under vacuum. The laws of solubility of gases in water indicate that to attain sufficiently low oxygen to prevent corrosion, the temperature should be at or near the boiling point for any particular pressure which in practice requires a prohibitive temperature, where the pressure is high, so that it has been found most economical to work deaerators at atmospheric pressure or lower.

The apparatus made by "Balke," of Bochum, Germany, for the extraction of gases from hot or cold water seems to have given good results. The water at normal temperature is violently sprayed into a chamber carrying a 90 per cent. vacuum, the disengaged gases being drawn off by an air pump into a condenser. The following results have been published in Mr. G. Paris' paper (*ibid*) :

	Amount of O_2 in cu. cent. per litre.		Amount of CO_2 in cu. cent. per litre.	
	Before Degasification	After Degasification	Before Degasification	After Degasification
Installation of 50 cu. metres, 90 per cent. vacuum, average temp. 20° C...	11.56	0	1.34	0
Installation of 50 cu. metres, 90 per cent. vacuum, average temp. 26° C...	8.6	0.03	19.65	0

[13] *Chemie et Industrie,* July, 1921.

The Coolgardie deaerator operating with water at a maximum temperature of 85° F. is reported to give over 80 per cent. extraction of gas at high vacuum. The residual oxygen reported with the Balke apparatus operating cold seems altogether too low to be attained under conditions described.

The "Balke" apparatus for degasifying hot water, several of which are reported to have been built, consists of : A horizontal tank with transverse vertical partitions so arranged as to cause the water heated by steam in the first compartment to pass up and down through a circuitous course. The gases given off are collected by a manifold connected to the top of each compartment into a common main. It will be seen that this is practically an open type feed water heater. The treated water is passed into a closed tank where it is kept out of contact with air by an atmosphere of steam or nitrogen. The following results are reported operating at 100° C. (*ibid.*) :

Installations	Amount of O_2 in c.c. per liter.		Amount of CO_2 in c.c. per liter.	
	Before Degasification	After Degasification	Before Degasification	After Degasification
Centrale Électrique de Trèves	10.50	0.22	1.13	0.00
Mine Adolphe	6.56	0.00	5.00	0.40
Westerwald	5.90	0.00	1.50	0.00

COMBINATION OF MECHANICAL AND CHEMICAL DEAERATION.

It is obvious from the laws governing the solubility of gases in water and experience with deaerators built on this principle, that the percentage of oxygen removal possible is limited to the theoretical saturation point of oxygen in water at any particular temperature and pressure, whereas chemical deactivation when given sufficient time will go on at any temperature and pressure until all the available oxygen is exhausted. It would therefore seem that where very large volumes of water have to be completely deaerated, or nearly so, an economical type of apparatus would be one in which the bulk of the free oxygen, which is easy to remove, is extracted by some simple and economical form of deaerator and the residual oxygen, say the last 5 or 10 per cent., by chemical treatment. The latter may be accomplished by a few minutes' contact with a suitable form of sheet iron scrap or by reac-

tion with ferrous hydrate from the addition of ferrous sulphate
and lime.   The action of ferrous hydrate is almost instantaneous
but requires a reliable proportional feed of reagents.   The

FIG. 13.
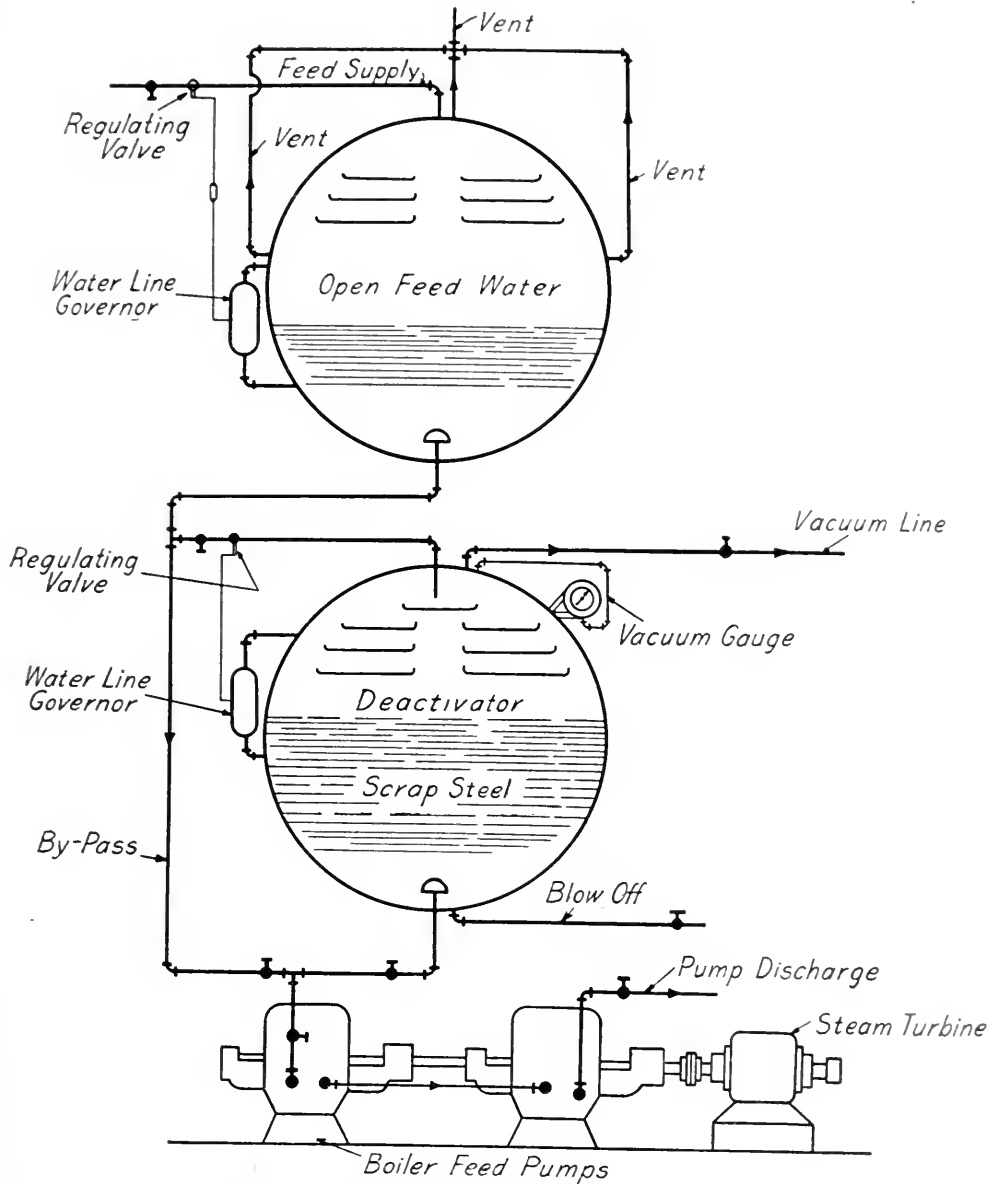
Combined deaerator and deactivator for boiler feed water.

combination of sheet iron deactivator with a preliminary deaera-
tion has been employed in treating the hot water of one of the
largest apartment houses of New York (Park Avenue and 48th
Street).   The water for the hot-water supply system is first put

TABLE I.

Summary of Results of Investigations of the Corrosion of Wrought Iron and Steel Pipe in Hot Water Supply Service.

Time Removed	Where Test Was Made	Length of Time Pipe Lines Were in Service	Authority and References	Number of Cases on Record	Average of Deepest Pits, Inches		Conclusions
					Wrought Iron	Steel	
1921	West 41st St. Public Baths, New York City.	4 yrs., 6 mos.	Chas. Baskerville, Prof. of Chem., College of the City of N.Y. Reported June 22, 1921.	Fourteen sections of steel of three different makes, 6 sections of wrought iron pipe.	0.0592	Lot (1) —— 0.0497 Lot (2) —— 0.0535 Lot (3) —— 0.0544 Average 0.0525	"Wrought iron showed deepest pitting. Appearance of corroded surfaces was charactersitic—wrought iron showing isolated 'pits', steel, a more general corrosion with 'lakes' well distributed with more or less uniformity. The more uniform corrosion of the steel is a fact of no little importance."
1921	West 41st St. Public Baths, New York City	10 years		Five sections of steel, 1 section of wrought iron pipe.	0.0606	0.0532	
1921	William Penn Hotel, Pittsburgh, Pa.	4 yrs., 7 mos.	Jas. O. Handy, Dir. Special Investigations, Pgh., Testing Lab. Reported July 11, 1921.	Four sections each of wrought iron and steel pipe.	0.1095	0.004	"Such differences, which confirm previous tests, are conclusive as to the relative resistance to corrosion of steel and wrought iron pipe in hot water lines."
1919	Irene Kaufmann Settlement, Pittsburgh, Pa.	2 yrs., 7 days	Jas. O. Handy, Technical Director, Pittsburgh Testing Laboratory. Report made to Resident Director Teller, Jan. 22, 1920; p. 97, Jan. 1920, A. S. H. & V. Engrs.; p. 276, Mar. 1920, A. S. H. & V. Engrs.	Fifteen lengths of steel, 15 lengths of wrought iron arranged alternately.	0.1144	0.1095	"These figures show that no marked distinction is possible between the rate of corrosion of the steel and the iron pipe."

Year & Place	Duration	Author / Reference	Description	Value	Values	Remarks
1919 Harvard University, Cambridge, Mass.	3 yrs.	Melville C. Whipple, Prof. of San. Chem., Harvard University. Jrn'l New England Water Wks. Assn.. p. 42, Mar, 1920.	Two sections each of scale-free (steel); galvanized steel, copper steel and wrought iron pipe.	0.073	Scale-Free 0.045 / Copper Steel 0.068 / Galvanized 0.078	"Judging from the depths of pitting and the general appearance of the inside of the pipe, it was evident that, so far as the conditions of this particular experiment with the Cambridge hot water service were concerned, scale-free pipe had suffered less real damage than any of the others after three years' exposure."
1918 Brown University, Providence, R. I.	11 mos.	Wm. F. Kenerson, Professor of Mechanical Engineering, Brown University. Report made June 7, 1918. Bulletin 2—"Corrosion of Hot Water Piping," National Tube Company.	Two sections each of black steel and wrought iron; one section each of galvanized and copper steel, galvanized.	0.0674	Black Steel 0.0544 / Copper Steel 0.0639 / Galvanized 0.0547 / Copper Steel Gal. 0.0938	"There is evidently no marked superiority of either the wrought iron or steel for the test conditions described. The wrought iron failed first by developing the deepest pits. The steel developed a greater number of shallower ones."
1917 This test was conducted in four different places as follows: (A) West 41st St. Bath, New York. (B) East 76th St. Bath, New York. (C) East 109th St. Bath, New York. (D) Cherry and Oliver Sts. Bath, New York	(A) 2 yrs. 9½ mos. (B) 2 yrs. 5 mos. (C) 2 yrs. 6 mos. (D) 2 yrs. 6 mos.	James S. Macgregor, Instructor in Civil Engineering, Columbia University. Report made Jan.—March, 1917. Bulletin 2—"Corrosion of Hot Water Piping." National Tube Co.	(A) 3 sections each of wrought iron and steel pipe. (B) 4 sections of steel and two of wrought iron (C) Same as test B. (D) One section each of steel and copper steel.	(A) 0.057 (B) 0.075 (C) 0.035	0.052 / 0.070 / 0.035 (D) Steel 0.021 / Copper Steel 0.022	Taking the total averages of steel (which include scale-free and copper steel, as well as ordinary black) pipe as against those for iron in the four tests, we find the latter to have pitted deeper by 0.025 in., which indicates in favor of steel pipe in these particular tests.
1916 Irene Kaufmann Settlement, Pittsburgh, Pa.	10 mos.	Jas. O. Handy, Technical Director, Pittsburgh Testing Laboratory. Report made October 31, 1916. P. 125, 1917 Trans. of A. S. H. & V. Engrs.	Seven sections of steel and 4 of wrought iron pipe.	0.116	0.110	The author states that a certain sample of wrought iron showed the most general corrosion, while a steel section showed the greatest number of separate pits. No direct reference to comparative corrosion is made.

through a deaerator of the type shown in Fig. 10, located a little below the stand-pipe on the roof, and is then brought down to a steel deactivator in the basement before entering the system. This gives almost perfect protection to the hot-water pipes. Another design for a combination plant for power plant service is shown in Fig. 13 [14] which includes an ordinary vented open-type heater from which the water is passed into a tank at lower pressure but not so low as to boil the water, so that no condenser is required. The residual oxygen amounting to about 0.5 c.c. per litre is finally extracted by passing through steel scrap placed in the lower part of the vacuum tank. A vacuum control apparatus is attached.

CONCLUSION.

From this outline of the present status of corrosion prevention by deactivation and deaeration of water, the reader may gather some idea of the important application of these principles to the conservation of iron and other metals in closed systems—*for what has been said of the protection afforded to iron applies equally well to brass and other metals which are subject to attack by water.* As a rule, cold water does not seriously attack pipes or tanks in the life of a building or pipe line, but there are notable exceptions to this rule. The experience with the Coolgardie (West Australia) 30-inch pipe line and the satisfactory results of partial deaeration show that this method of protection can in some cases be economically applied to cold water when necessary. This would seem to apply particularly to cold as well as to hot salt water used in large seaside hotels, which cause considerable damage and costly repairs. While the laws underlying corrosion are now fairly well established, the economic application of these laws require a detailed knowledge of existing conditions interpreted in the light of previous experience as in all engineering development. Much yet remains to be done in perfecting details, but the results already obtained are sufficient to indicate the permanent benefits to be derived through the application of these principles.

---

[14] Designed by the Anti-Corrosion Engineering Company, New York, U. S. A.

NOTES FROM THE U. S. BUREAU OF STANDARDS.*

NOTE ON THE PREPARATION OF MANNOSE.[1]

By E. P. Clark.

[ABSTRACT.]

SIFTED ivory nut shavings are added to 10 times their weight of boiling 1 per cent. sodium hydroxide solution. The mixture is at once removed from the source of heat and stirred occasionally during the ½ hour. The shavings are then washed thoroughly with running water until neutral and clear, and dried.

Five hundred grams of the material, thus prepared, are thoroughly mixed with 500 grams of 75 per cent. sulphuric acid and allowed to stand until the next day. This mass is dissolved in water, making a volume of 5.5 litres, and boiled under reflux for 2½ hours. While the liquid is still boiling, it is neutralized with a thin paste of precipitated barium carbonate. The solution is at once filtered through a thin layer of active carbon placed on moistened filter paper in a Büchner funnel. The filtrate generally contains a little barium, probably in combination with organic acids. This is removed by adding a few c.c. of dilute sulphuric acid until no further precipitate is formed. The barium sulphate is filtered off and the solution evaporated under reduced pressure to 87–88 per cent. total solids. An equal volume of glacial acetic acid is added and thoroughly mixed by warming and shaking. The syrup is seeded, placed in an ice box over night for crystallization to start, and it is then frozen with an ice-salt mixture. The frozen mass is placed in a refrigerator at or near 0° C., where it will thaw out slowly. After about a day the greater portion of the sugar will often have crystallized, but generally a week is required for complete crystallization. The yield is uniformly 42–45 per cent. of the treated meal used.

---

* Communicated by the Director.

[1] Scientific Papers No. 429.

HIGH-FREQUENCY RESISTANCE OF INDUCTANCE COILS.[1]

By G. Breit.

[ABSTRACT.]

For direct current the resistance of inductance coils can be defined by means of Ohm's law. At high frequencies Ohm's law does not give complete information about the current flow, because the current flow is modified by induction effects of magnetic as well as electrostatic nature. As a result the current density is not uniform over a given cross-section of a wire, nor is it the same for different cross-sections of the wire. The study of non-uniformity of current density in a cross-section is the subject of skin effect, which is not discussed in this paper, although the well-known results as to skin effect are used.

The non-uniformity of current with respect to different cross-sections has not been treated before to any extent. It is the purpose of the investigation described in this paper to calculate the effects of this non-uniformity and also to measure them. The non-uniformity with respect to different cross-sections is caused by the capacities distributed along the winding of the coil. These capacities cause charges to collect at various points on the wires of the coil, and this results in the current having different values at different points in the coil.

There are several effects of the non-uniform distribution of current along the wire. The most important, however, is the increase in the resistance of the coil with the frequency. An expression for the resistance of an inductance coil is derived which takes into consideration both the skin effect and the capacity effect for the case of a short, single-layer solenoid, and the formula is verified experimentally.

The other effect considered is that of the relative importance of emf's having the same value but impressed at different points of the coil. The emf is more effective in setting up current at all points of the coil when it is impressed at a current loop.

It is also shown that the resistance as measured by the resistance-variation method with respect to different points in the coil depends in a definite manner on the current distribution. If

---

[1] Scientific Papers No. 430.

R_1, R_2 are the measured values of resistance and if i_1, i_2 are corresponding values of the current, then

$$i_1\sqrt{R_1} = i_2\sqrt{R_2}$$

provided the coil can be considered as made of a nearly perfectly conducting material.

It is also shown that at a given point of the coil the current i_0 may be computed if the emf induced in any coil portion is known and if the value of the resistance measured by the resistance-variation method is known for all points of the coil. These computations are then applied to coil aerials and the results are verified experimentally.

EFFECT OF HEAT-TREATMENT ON THE MECHANICAL PROPERTIES ON ONE PER CENT. CARBON STEEL.[3]

By H. J. French and W. George Johnson.

[ABSTRACT.]

THIS paper gives the effects of varying time-temperature relations in heat-treatment on tensile and impact properties, hardness, and structure of one per cent. carbon steel as follows: (a) Effect of temperature variations in hardening; (b) time at hardening temperatures both above Acm and between the Ac_1 and Acm transformation; (c) effects of tempering steel hardened in different ways and effects of " soaking " just under the lower critical range; (d) comparison of oil and water hardening for production of definite strengths.

Under the described conditions of treatment and test the following features are observed:

(1) The most suitable oil or water quenching temperature for steel which is subsequently to be tempered at relatively high temperatures is slightly above the end of the Ac_1 transformation.

(2) With increase in oil quenching temperature for steel subsequently tempered at 538° C. (1000° F.) hardness, strength and limit of proportionality increase and maximum values are obtained after quenching from 843° C. (1550° F.) which is coincident with retention of all but a small portion of the excess cementite. A higher quenching temperature results in decreased strength.

(3) When this steel is subsequently to be tempered to produce a tensile strength in the neighborhood of 120,000 pounds per

---

[3] Technologic Paper No. 206.

square inch water quenching is to be preferred on account of the higher elastic ratio produced, always assuming that the size and shape of material is such as to allow drastic treatment. If higher strength is desired, oil quenching from just above the Ac_1 transformation will give slightly better combinations of strength and ductility but with lower elastic ratio than are obtained by water hardening.

(4) A lower tempering temperature is required after water hardening than when cooling in oil from the same temperature in order to produce the same strength. This difference in temperature in general increases the higher the strength required (the lower the tempering temperatures).

(5) When samples are quenched in water and others quenched in oil and all so tempered as to produce the same strength the water quenched steel will have the highest hardness as determined by the Brinell and Shore methods.

(6) While good combinations of tensile strength and ductility may be obtained by tempering at the higher tempering temperatures the steel is brittle and has low resistance to impact. This is shown by the much higher combinations of strength and ductility obtained in tensile tests when the steel is ground to size after heat-treatment and by the low Charpy and Izod values obtained in all cases.

(7) Increased time at hardening temperatures results in increased hardness, strength and limit of proportionality and decreased ductility as does rise in temperature.

(8) Long time heating just under the lower critical range results in a material softening of the steel, equivalent to a decrease of 40 per cent. in Brinell hardness and 20 per cent. in Shore hardness when the time at temperature is increased from 30 minutes to 5 hours. Short-time heating in this temperature range results in a softer steel than that air cooled from above the transformations.

MANUFACTURE AND PROPERTIES OF STEEL PLATES CONTAINING ZIRCONIUM AND OTHER ELEMENTS.[1]

By George K. Burgess and Raymond W. Woodward.

[ABSTRACT.]

This investigation originated from the need of the Ordnance Department of the Army and Navy for information regarding the

---
[1] Technologic Paper No. 207.

effects of the ballistic properties of light armor plate of certain chemical elements such as zirconium.

A joint program was outlined according to which the Bureau of Mines was to produce and analyze ingots of the desired compositions; the Bureau of Standards to manufacture and heat-treat plates, carry out physical tests, micro-examinations and chemical analyses, and develop methods of chemical analysis, when needed, for the more unusual elements in steel and in the presence of each other; and the Navy Department was to carry out the ballistic tests.

Although the results of the ballistic tests are not available for publication, an account of the mechanical properties and tests of this series of somewhat unusual steels was considered worthy of publication.   These results may be summarized as follows:

About 193 heats of steel containing in various combinations the following principal variable elements: Carbon, silicon, nickel, aluminum, titanium, zirconium, cerium, boron, copper, cobalt, uranium, molybdenum, chromium and tungsten, have been studied.

None of the steels presented any difficulties in rolling into plate except those containing boron.

The usual mechanical properties and impact tests were carried out on all of the steels.   It is shown that steel containing 0.40 to 0.50 per cent. carbon, 1.00 to 1.50 per cent. silicon, 3.00 to 3.25 per cent. nickel, and 0.60 to 0.80 manganese and deoxidized with a simple deoxidizer such as aluminum can be produced having a tensile strength of approximately 300,000 pounds to the square inch, with excellent ductility and toughness.   This type of steel is recommended for a structural material.

Although the same high properties are obtained in steels of the above composition with the aid of additional elements it does not appear necessary to resort to such additions of expensive alloying elements.

Zirconium, like titanium and aluminum, acts primarily as a scavanger, and when it is not removed as part of the slag remains in the steel in the form of square bright yellow inclusions not directly visible at magnifications lower than 500 x.   It is not considered that these inclusions can be very beneficial, and if they are segregated and rolled out into thin plate-like streaks they may be detrimental, especially in armor plate.

Of the other elements that are regarded as special alloying ad-

ditions, chromium, tungsten, vanadium and molybdenum go into solution and produce a martensitic pattern in the air-cooled specimens. Cerium and uranium act in a similar manner but also show characteristic inclusions. Copper goes into solution but a larger amount is required to produce a martensitic pattern in the air-cooled samples than for the others. Borons forms a complex eutectic, probably that of an iron-carbon-boron compound with iron. This eutectic is fusible at the temperatures ordinarily used in rolling, but at slightly lower temperatures steel containing boron can be rolled successfully. Hot working breaks up the eutectic and spherical hard particles, similar to iron carbide globules, are formed.

REPORT OF 14th ANNUAL CONFERENCE ON WEIGHTS AND MEASURES.[5]

[ABSTRACT.]

This publication is a verbatim report of the Fourteenth Annual Conference on Weights and Measures, an organization composed of state and local officials engaged in the enforcement of weights and measures laws throughout the United States. The conferences are held to promote uniformity in weights and measures laws, rules and regulations, and specifications and tolerances, and the enforcement thereof in methods of inspection of apparatus.

The Secretary of Commerce gave an address pointing out the necessity for proper supervision of weights and measures and the president of the conference and Director of the Bureau of Standards outlined advances made during the year. State and local officials gave reports on conditions in their respective jurisdictions, the majority of which indicated that conditions were gradually improving, that the work was gaining in public importance, and that excellent legislation was being enacted.

Perhaps the most important single accomplishment of the present conference was the adoption of a proposed model law for the sale of bread, the text of this being agreed upon after several papers had been delivered by representatives of the baking industry and of the officials, and a general discussion held. In brief, this law proposes standardization of the loaves and provides

---

[5] Miscellaneous Publication No. 48.

that bread shall be sold only in loaves weighing one-half pound, one pound, one and one-half pounds or multiples of a pound.

The specifications and tolerances for liquid-measuring devices adopted by the preceding conference were reviewed and several changes were made, the advisibility of which was indicated by the enforcement of the regulations in the field during the year. New tolerances were adopted, two cubic inches being allowed on deliveries of one-half gallon or less, three cubic inches on a gallon delivery, and one cubic inch per gallon additional in the case of deliveries of more than this amount. These serve to increase the former tolerance on small deliveries and decrease it on large deliveries. Also it was provided that the tolerance in excess only is not to be applied to condemn pumps on tests of deliveries made at a more rapid speed than normal speed of delivery. Some of the more important changes in specifications were as follows: Allowing two delivery outlets when deliveries are properly safeguarded; adding the two and one-half gallon size to the allowable capacities for devices; adding to the scope of the regulations by including devices intended to be attached to and used in connection with liquid-measuring devices; and allowing scales with non-parallel lines when proper indication is obtainable. There was a general discussion of the application of retroactive specifications for liquid-measuring devices.

There was referred to the Committee on Specifications and Tolerances for consideration during the coming year and report to the next conference the question of tolerances on bread weights, and specifications and tolerances on heavy-duty automatic scales, fabric-measuring devices, and tank wagons it being developed in discussion that additional regulations for these devices were becoming necessary. Among the resolutions adopted were endorsements of the slack-filled package bill, and of the principles of national serialization of type of apparatus and of the simplification of packages and containers. The metric system of weights and measures was discussed and it was decided to give this subject a prominent place on the program of the next conference.

Some of the other subjects upon which there were papers and discussions were as follows: The mine scale work of the Bureau of Standards; the proper methods of test of liquid-measuring devices; the enforcement of the federal law requiring the marking of the weight on wrapped meats; the general methods of detecting

violations and proceeding against offenders; the destination weighing of coal in car-load lots; and the education of the public to the necessity of accurate weights.

The appendixes contain the specifications and tolerances for liquid-measuring devices as amended by the conference; the text of the model bread law adopted, and a new section on this subject in conformity with the above to be inserted in the proposed general model state law on weights and measures adopted by previous conferences and recommended to the various states for enactment.

SPECIFICATIONS FOR LIME-FLINT GLASS TUMBLERS.[6]

[ABSTRACT.]

SPECIFICATIONS are given for a plain pressed hotel tumbler made of lime-flint glass. The items include the designation, measurements, material, quality, tolerance in size and weight, shock test, boiling test, acceptance, and sampling. They were formulated under the auspices of the Bureau of Standards and have been accepted by the Army, Navy and Marine Corps, Public Health Service, and General Supply Committee of the United States Government. At least 95 per cent. of the samples must pass all tests. The tests include five fillings with boiling water with sample at room temperature at the start (the shock test); and boiling for six hours to disclose any sign of corrosion, scumming, chipping, or cracking (boiling test). Traces of color or bubbles if not unsightly are allowed, but there must be no stones, cords, nor fine cracks. The dimensions, weight, and capacity are specified with the minimum and maximum allowable for each.

An Investigation of the Constancy in Wave-length of the Atmospheric and Solar Lines. C. E. St. John and H. D. Babcock. (*Astrophys. J.,* Jan., 1922.)—A few years ago Perot reported a series of observations on the wave-length of atmospheric lines in the solar spectrum. According to him the wave-length of an oxygen line in the B group increased from morning to noon, after which time it grew less. These results are contradicted by careful measurements made on 25 plates taken at Mount Wilson Observatory. The variation is within the limits of accidental error.

G. F. S.

---

[6] Circular No. 119.

NOTES FROM THE LABORATORY OF PURE SCIENCE
NELA RESEARCH LABORATORIES.*

A METHOD FOR INCREASING THE CARRYING CAPACITY OF A RHEOSTAT.

By W. E. Forsythe.

WHEN using an ordinary slide resistance to control a current it often happens that when the current is the largest only a small part of the resistance is being used. This may be disadvantageous for two reasons: In the first place, the smallest change possible in this small part of the resistance may greatly increase the current, and in the second place, the resistance may be very much overheated. To overcome these difficulties a method has been devised

FIG. 1.
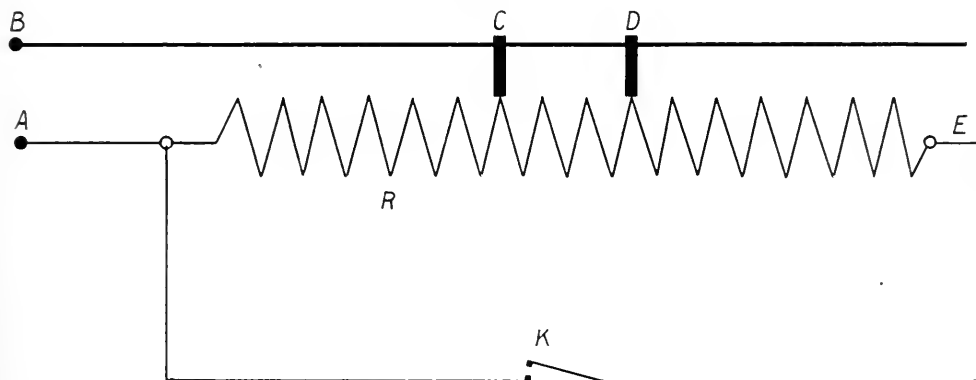
whereby it is possible to use both ends of the rheostat and thereby double its carrying capacity and at the same time make current control easier and more accurate. In Fig. 1 is shown diagrammatically a slide rheostat with the additions necessary in order that both ends can be used.

The current ordinarily enters at the binding post A, passes through the resistance R and out at the binding post B through the slide C. As the slide C is moved towards A to increase the current, more and more of the resistance is cut out of the circuit and is not used. To change the rheostat so as to double

its carrying capacity put on a second slide, *D*, a second binding post, *E,* at the end of the rheostat opposite *A* and a switch, *K*, so connected that when it is closed the two binding posts, *A* and *E,* are connected.   To operate the rheostat proceed in the ordinary manner (switch *K* open) with the current entering at *A* passing through the resistance *R,* the slide *C* and out at *B*.   To increase the current, move this slide towards *A* until it has passed over three-fourths of the distance from *E* to *A*.   To obtain a larger current move both slides to the centre of the resistance *R* and close the switch *K*.   The resistance will be about the same as it was with one slide and one-fourth of the resistance in use. The current will be divided at *A* and one-half of it will enter at *E* and pass out at *D*, the other half entering at *A* and passing out at *C*.   To increase the current move either slide *C* towards *A,* slide *D* towards *E,.* or move the two slides farther apart.   If a better control of the current is wanted increase the current to about the desired value by moving but one slide and make final adjustment by sliding the second contact forward or back.

Two such rheostats have been made in Nela Research Laboratories and used regularly for a year or more and found convenient and satisfactory.   It is often convenient to control a current of fifty to sixty amperes with a rheostat originally constructed to carry but thirty.

CLEVELAND, OHIO,
   March, 1922.

An Interesting Case of Mechanical Disintegration Caused by Positive Ions. H. P. WARAN. (*Phil. Mag.*, January, 1922.)— The capillary of an ordinary Pluecker tube, with a pressure of a few mm., was placed between the conical poles of an electromagnet. When the tube was traversed by an unrectified current from an induction coil, the electron stream was deflected first against one side wall of the glass and then against the other. When an especially strong current passed, it took only a few seconds for a gray patch to develop on the glass "indicating a corrosion of the glass under the sand-blast action of the ions." A quite definite fish-bone pattern is produced, but the arrangements on the two sides of the glass tube are reversed. "There can be little doubt that this grooving of the glass was effected by the bombardment of the massive positive ions which travel in opposite directions in the two streams causing grooves that converge in opposite directions."

                                                  G. F. S.

NOTES FROM THE RESEARCH LABORATORY
EASTMAN KODAK COMPANY.*

THE ELASTIC PROPERTIES OF GELATIN JELLIES.[1]
By S. E. Sheppard and S. S. Sweet.

THIS is a continuation of work previously reported dealing with the determination of the modulus of elasticity of gelatin jellies of various concentrations. The authors give measurements of the rigidity of gelatin jellies showing that the jellies follow Hooke's law nearly up to the breaking point. The relation of the modulus of elasticity to the concentration of gelatin is discussed. It is found that a function of the type $D = k \, c^n$ is valid for a certain range, but that the constants K and n may vary from one grade of gelatin to another. The influence of acidity and alkalinity on the elasticity has been followed quantitatively. p_H measurements show that the observed variations in the elasticity are not a simple function of the actual hydrogen ion concentration. The influence of alcohol and glycerol in different concentrations on the coefficient of rigidity have been measured.

THE EFFICIENCY OF THE BUCKY DIAPHRAGM PRINCIPLE.[2]
By R. B. Wilsey.

USING a six-inch depth of water as the scattering material, the efficiency of the Bucky diaphragm in removing scattered x-radiation has been measured for a variety of widths and depths of slit. The intensity of diffuse radiation was found to be a function of the ratio of slit width to slit depth, not depending on the actual size of the slit. The Bucky diaphragm was found to be highly efficient, it being easily possible to remove 80 to 90 per cent. of the scattered radiation. The wood filler used to support the lead strips has only a slight effect upon the efficiency of

---

the diaphragm; for small sizes of slit, its influence is practically negligible.

The definition obtainable with the Bucky diaphragm depends chiefly on the distance between the subject röntgenographed and the film; by making this distance sufficiently small (⅜ inch or less), the Bucky diaphragm can be made to give a considerable improvement in definition over the ordinary technic, and can be used with advantage in röntgenographing thicknesses as small as four inches.

The crossed grid of the original Bucky type (resembling a honeycomb) gives very little advantage over the Potter type of grid with the same depth of slit; it is concluded that the best practical improvement of the Bucky diaphragm lies in pushing the Potter type of grid to the limit of its effectiveness, that is, by making the grid as thin and as fine meshed as possible.

Characteristic X-rays from Carbon and Boron. A. L. Hughes. (*Phil. Mag.*, January, 1922.)—There is a considerable gap between the longest X-ray wave-lengths and the shortest lengths in the ultra-violet. Unless very recent progress has been made, the longest X-rays, a K line from sodium and an L line from zinc, had the length of about 12 Ångstrom units, while the shortest line in the ultra-violet yet photographed is 202 units in wave-length. The gap is consequently a little over four octaves in extent. "There is no reason to believe that X-rays of still longer wave-length cannot be produced, but no crystal has been found, or is likely to be found, with spacings between its planes sufficiently large to measure appreciably longer wave-lengths. It is unlikely, therefore, that the spectrum can be extended more than a few Ångstrom units by the method of crystal analysis." A different method must therefore be used. Building on the experimental foundation laid by Beatty and others, the experimenter directed a stream of electrons upon a boron target, let the resulting X-rays fall on a metal plate that gave off photo-electrons under the excitation and measured this photo-electric current. By increasing step by step the energy of the incident electrons a point is reached when the characteristic radiation of the boron begins to be emitted. This condition is recognized by a marked increase in the photo-electric current. There is a known relation existing between the potential accelerating the electrons and the wave-length of the characteristic radiation developed. From this the latter is calculated, and is found to be 83.5 units, while for carbon the length of 57.5 units is obtained. This is indeed a notable extension of the X-ray spectrum.

G. F. S.

NOTES FROM THE U. S. BUREAU OF CHEMISTRY.*

THE CHEMICAL COMPOSITION OF CORN OIL.[1]

By Walter F. Baughman and George S. Jamieson.

[ABSTRACT.]

THE oil used for this investigation was expressed from dry process corn germs by an oil expeller. The following physical and chemical characteristics were determined:

Specific gravity 25/25–C....................	0.9185
Refractive index 20° C......................	1.4717
Iodine number (Hanus)	117.2
Saponification value	187.3
Unsaponifiable matter (per cent.)............	1.7
Acid value	2.5
Acetyl value	10.0
Saturated acids (per cent.)..................	11.2
Unsaturated acids (per cent.)...............	82.5

The chemical composition of the corn oil was as follows:

		Per cent.
	Oleic acid	45.4
	Linolic acid	40.9
	Palmitic acid	7.7
Glycerides of	Stearic acid	3.5
	Arachidic acid	0.4
	Lignoceric acid	0.2
	Unsaponifiable	1.7
		99.8

It is interesting to note that Hehner and Mitchell (*Analyst*, 21 (1896) : 328) could not detect stearic acid in corn oil, while Lewkowitsch quotes Vulte and Gibson as authority for the statement that the saturated acids of corn oil consist of palmitic, stearic, and arachidic acids. The results of the Bureau's investigation confirm Gibson's statement and show in addition the presence of a small amount of lignoceric acid.

---

* Communicated by the Chief of the Bureau.
[1] Published in *J. Amer. Chem. Soc.*, **43** (1921) : 2696.

THE SOURCES AND CHARACTERISTICS OF THE BACTERIA IN DECOMPOSING SALMON.[2]

By Albert C. Hunter.

[ABSTRACT.]

In studying the distribution of the bacteria concerned in the decomposition of salmon, 316 cultures were collected from sea-water, from decomposing salmon and from salmon canneries throughout southeastern Alaska. After discarding those cultures which were soon recognized as duplicate, 85 cultures were kept for further study. One of these cultures was actinomyces, one was a pink yeast, and four were white yeasts. Of the remaining 79 cultures, 72 were rod-shaped organisms without spores, 3 were spore-forming rods, and 4 were streptococci.

While no attempt was made to specifically identify many of the cultures, six were identified as *Bact. cloacæ,* three as *Bact. aerogenes,* two as *Bact. coli,* one as *Bact. communior,* and four as *Ps. fluorescens.* The majority of the bacteria collected apparently belong to a large group of non-fermenting soil and water bacteria.

Of the original 316 cultures, 71 were *Ps. fluorescens,* 27 were *Bact. cloacæ,* and 12 were cultures of an unidentified flesh-colored organism represented as Culture 360. The predominance of these three organisms, when considered in connection with their decomposing action on salmon, indicates that they play an important part in the decomposition of the salmon.

Eighty per cent. of the bacteria collected from sea-water were also found in decomposing salmon, in the canneries, or in both. Approximately 52 per cent. of the salmon cultures were also found in sea-water or in the canneries, and about 34 per cent. of the cultures from the Alaskan canneries were also obtained from other sources.

The results of this investigation confirm the statement previously made that the bacteria concerned in the decomposition of salmon are those forms which are regularly found in the sea-water from which the salmon are taken, and that the decomposition of salmon is not due to bacteria which contaminate the salmon within the cannery.

VIABILITY OF THE COLON-TYPHOID GROUP IN CARBONATED WATER AND CARBONATED BEVERAGES.[3]

By S. A. Koser and W. W. Skinner.

[ABSTRACT.]

Carbonation exerts a distinctly harmful effect upon the members of the colon-typhoid group, the period of viability of which is much shorter in carbonated water than in plain tap water. The destructive effect of the carbon dioxide is especially marked at room temperature (19 to 23° C.); it is less marked at 1° C.

The organisms may persist for a slightly longer period in a "non-acid" beverage than in carbonated water. In beverages containing 0.094 per cent. or more of citric or lactic acids, the death-rate is very rapid, being due apparently to the effect of these two acids.

Bact. typhosum and *Bact. paratyphosum B* are more readily destroyed by carbon dioxide than is *Bact. coli.*

The spore forms of a common aerobe, *B. mesentericus*, and of a common anaerobe, *Clost. sporogenes*, proved to be quite resistant to carbonation, surviving for one month at room temperature with no apparent diminution in numbers.

New Measurements of Stellar Radiation. W. W. Coblentz. (*Astrophys. J.*, Jan., 1922.)—These measurements were carried out at the Lowell Observatory, Flagstaff, Arizona, with the use of a vacuum thermo-couple and confirm certain conclusions derived from observations made at the lower altitude of the Lick Observatory. If a red star and a blue star appear to be of the same magnitude, the red star emits from 2.5 to 3 times as much total radiation as the blue one. If three stars, respectively blue, yellow and red, emit the same amount of total radiation, then the blue star emits twice as much visible radiation as the yellow star and three times as much as the red one.

By means of transmission screens the distribution of energy in the spectra of 16 stars was determined. The percentage of stellar energy transmitted through a layer of water one cm. thick was measured. These are some of the results: Rigel, 63; Castor, 82; Sirius, 65; Capella, 57; Aldebaran, 42; Betelgeuse, 34. The blue stars emit a smaller amount of infra-red radiation than do red stars of the same apparent magnitude.

G. F. S.

At the meeting of the French Physical Society on December 16, 1921, A. Perard reported on progress made with the quartz standards of length recommended by the International Committee on Weights and Measures. These are square prisms, 25 mm. on a side with the edges parallel to the crystallographic axis. The length embodied by each prism is not the distance between two cross lines but the distance between the two accurate and parallel planes forming the ends. Two interference methods based on Michelson's arrangement are used to measure the length. It is not necessary to silver the ends of the prism. By one of these methods prisms of the several lengths, 1, 2, 4, 10 and 20 mm., have been measured. In the discussion which followed the paper Professor Fabry directed attention to the difficulty of obtaining satisfactory sources of monochromatic light for metrological purposes. Commercial mercury vapor lamps are durable and convenient, but unfortunately each line has satellites. The cadmium tube to produce the red X-ray in the wave-length of which standard lengths are now expressed is not only fragile but has to be made in the laboratory. Neon gives light that will prove of use in accurate measurements and its commercial applications make it easy to get. The rays of krypton are exceptionally sharp, but this gas is hard to obtain in France. The construction of tubes filled with this gas would have little or no practical value, but, on the other hand, would be of distinct scientific advantage.

G. F. S.

Radium for England. (*Science,* Oct. 21, 1921.)—Frederick Soddy, professor of chemistry in Oxford, visited the Joachimsthal mines in Czecho-Slovakia and inspected them thoroughly, seeing also the processes for extracting radium from the pitchblende. On his return he brought with him to England two grams of radium, valued at £70,000. The transportation of so large a mass of this substance was not an easy matter in view of the constant emission of particles at enormous velocities. The radium was divided up between nine glass phials placed within a case of lead three inches thick and Doctor Soddy travelled as a King's Messenger. Upon his arrival his precious burden was deposited in the Foreign Office. The owner of the radium, The Imperial and Foreign Corporation of London, has an agreement with the Czecho-Slovakian government by which it gets the loan of the radium output of the mines for a period of fifteen years, less an amount reserved for public use. The state will continue to work the mines.

The Corporation expects to make use of its recent importation thus: " The radium will be lent freely for hospital purposes, and rented out to private practitioners. It will also be used for the production and sale of radio-active water in bottles, for use at radio-sanatoria, the production and sale of radio-active fertilizers, and for its by-products, such as polonium."

G. F. S.

NOTES FROM THE U. S. BUREAU OF MINES.*

PERMEABILITY OF REFRACTORIES TO AIR.

By H. W. Douda.

THE porosity of a refractory has generally been used as an indication of the suitability of the raw material for use in making refractories. Permeability to air has now been utilized as a measure of the same property. Fire clay, bauxite, silica, magnesite, zirkite, graphite, and insulating bricks were tested.

A known volume of air was passed through a cylindrical section of brick, by displacement with water and the pressure and time were noted at each drop of 50 c.c.

Permeability may be expressed as the number of cubic centimetres of air passing through a mass of refractory, one square centimetre in cross-section by one centimetre long, in one second under a pressure of one centimetre of water.

Permeability is not directly proportional to porosity but is more dependent on pore structure, and to various degrees on temperature of burning, size of grain and method of manufacture. It has been more fully discussed in a paper recently presented by the author before the American Ceramic Society.

THE PROPERTIES OF SOME CLAY-LIKE MINERALS OF THE BENTONITE TYPE.

By H. G. Schurecht and H. W. Douda.

BENTONITES are probably aggregates of alkaline hydrated silica and kaolinite in varying proportions. They, as is indicated in a more complete discussion of them by the authors, before the American Ceramic Society, are characterized by the following properties: Conchoidal fracture; an index of refraction between 1.48 and 1.54; high water of plasticity and high volume drying shrinkage, varying from those of highly plastic clays to 114.61 and 195.8 per cent., respectively; and a high content of alkali plus alkaline earth, usually more than 5 per cent. When added

---

* Communicated by the Director.

to clays they increase the bonding power to a remarkable extent. In firing they vitrify below 1000° C., soften at cones 1 to 14, and burn to a buff to brown color. Because of this color they can only be used in small amounts in whiteware.

It is possible by adding quartz and bentonite to certain fire clays to produce clays approaching the Gross Almerode and Arkansas glass pot clays in properties.

PROPERTIES OF KANSAS CRUDES.

By E. W. Dean.

The Bureau has recently completed a survey of crude oils from the Kansas district, which is part of a general survey of crude oils from all the producing fields of the United States. Work on samples from the Eastern fields, Rocky Mountain districts, and the fields of northern Texas, northern Louisiana, and Arkansas, had been previously completed and the results published.

The distillations of the Kansas crudes indicate a narrow gravity range, most of them falling between 27° and 37° B, with a minimum of 19.4° and a maximum of 43.5° B. Sulphur content varied from 0.12 to 0.66 per cent., most of the samples falling between 0.20 and 0.40 per cent. The gasoline-naphtha content ranged from 10 to 30 per cent., averaging 22.3 per cent. The gasoline and naphtha were grouped together in making the distillations, so that the figures are somewhat more favorable than are generally attributed to Kansas crudes. Further details are given in a report recently published by the Bureau of Mines in mimeograph form.

USE OF LOW-PRESSURE GAS IN OIL FIELD BURNERS.

By M. P. Youker.

Large quantities of low-pressure gas are wasted into the air in vicinities where drilling operations are being carried on by the use of oil or high-pressure gas. If the low-pressure gas could be used, marketable fuels would thus be conserved, and frequently the entire cost of fuel for drilling saved to the operator. The Bureau of Mines, in coöperation with the Osage Oil and Gas Lessees Association and the Osage Indian Agency, has conducted

experiments to determine whether low-pressure gas can be used to advantage in oil field boilers to generate steam for drilling and what types of burners would be best for this purpose.

The steam consumption of the ordinary drilling equipment was determined in the field, after which a test boiler was installed at the petroleum experiment station of the Bureau, at Bartlesville, Oklahoma, and various types of low-pressure gas burners were tested under conditions approximating actual field loads. Of 11 burners tested, 9 were found to have sufficient capacity to operate a standard rig drilling to depths of 2800 feet, at gas pressures below 5 pounds at the burner, and some of the burners required less than one pound gas pressure. Further details of the results will be found in the complete report of this investigation, printed as part of the Year-book of the Mid-Continent Oil and Gas Association, Tulsa, Oklahoma.

Fall of Potential and Vertical Conduction Currents of Electricity in the Free Atmosphere. E. Everling and A. Wigand. (*Ann. d. Physik*, No. 20, 1921.)—It has been known for a long time that the atmosphere has higher potential than the earth itself. Accordingly in coming down through the air there is a fall of potential. Moreover the air has a certain conductivity. Then since it can conduct, and since there is a fall of potential downward along the vertical, it follows that currents flow through it downward toward the earth. From quite a different point of view, L. A. Bauer has established the existence of such currents by the formation of line integrals.

The two German meteorologists present the results of two balloon flights reaching up to almost 9 km. (5.5 miles). They found that the fall of potential, which has a value of about 27 volts per metre at a height of 2.5 km. above the earth, at first diminishes quite rapidly with height, then more slowly, and that it seems to have a value of no more than 4 volts per metre when an elevation of 9 km. is attained.

The conductivity of the air, on the other hand, is much less near the earth than at greater altitudes. At 3.5 km. it is nine or ten times as great as it is a few metres above the earth's surface. By combining the results of conductivity with those for the fall of potential the vertical earth currents were calculated. There is not so much change in these with altitude, but there is a recognizable decrease as the elevation grows greater.

The authors deserve credit for their scientific enthusiasm which led them to perform such experiments in the car of a balloon where each was cramped for space and where the usual operation of their lungs had to be artificially supplemented.   G. F. S.

Measurement of the Thomson Effect at Low Temperatures.
G. BORELIUS and F. GUNNESON. (*Ann. d. Physik.*, No. 14, 1921.)—
If the middle point of a metal wire be kept at one temperature, while
the two ends are maintained at some different temperature alike for
both, then with symmetrical conditions two points of the wire at the
same distance from the middle would have the same temperature.
Let now an electric current flow from one end of the wire to the other.
In one-half of the wire it goes uphill as regards temperature and in
the other half downhill. The two points which previously had the
same temperature now are found to have different temperatures.
One point has grown warmer while the other is cooler. Lord
Kelvin inferred the existence of this phenomenon and confirmed his
conclusions by experiment. Hence the designation " Thomson
Effect." The effect is reversed in sign when the current is reversed
and at a given temperature the direction is dependent upon the metal
of the wire.

The two investigators in the University of Lund have examined
copper, silver, gold, zinc, cadmium, tin and lead from the temperature
of liquid air to that of boiling water. In the cases of copper, silver,
cadmium and tin there is a temperature within the specified range
at which the direction of the effect reverses itself, that is, if the
current flows toward parts of the wire at higher temperatures and
in so doing raises the temperature of the wire, then upon elevating
sufficiently the temperature of the wire the current will no longer
raise but will on the contrary lower the temperature. No such
change was observed with gold, zinc, and lead. When curves are
plotted connecting temperature with volts per degree for copper,
silver and gold the forms are similar as might be expected from the
relations of these metals in the Periodic System. The results are
given in micro-volts (millionths of a volt) per degree. Cadmium
displays the greatest change with temperature—0 at 150° abs. to 9.8
at 380° abs. Lead is very conservative in its changes in comparison
with cadmium.

<div style="text-align:right">G. F. S.</div>

Encouragement of Research on Glass.—With a view of secur-
ing additional information concerning the chemistry and physics of
glass, a Committee of the American Ceramic Society has made ar-
rangements for providing investigators with samples of desired
composition and form. These will be supplied without charge, the
only conditions being that the recipients shall proceed with investi-
gations and furnish the results for publication. The following are
the members of the Committee, to any one of whom the application
for samples may be made: E. C. Sullivan, Corning Glass Works,
Corning, New York; E. W. Washburn, University of Illinois,
Urbana, Illinois, and R. B. Sosman, Geophysical Laboratory,
Washington, D. C. H. L.

THE FRANKLIN INSTITUTE.

(Proceedings of the Stated Meeting held Wednesday, March 15, 1922.)

HALL OF THE FRANKLIN INSTITUTE,
PHILADELPHIA, March 15, 1922.

DR. WALTON CLARK, President of the Institute, *in the Chair.*

The Board of Managers submitted its report. The report recorded the election to membership of:

J. L. Crenshaw, Ph.D.,
Associate Professor of Physical Chemistry,
Swarthmore College,
Swarthmore, Pennsylvania.

Isaac H. Francis, M E.,
Consulting Mechanical Engineer,
Otis Building,
Philadelphia, Pennsylvania.

D. H. Kabakjian, Ph.D.,
Assistant Professor of Physics,
University of Pennsylvania,
Philadelphia, Pennsylvania.

Theodore S. Rowland, A.B.,
Head of Science Department.
Northeast High School,
Philadelphia, Pennsylvania.

Alexander S. Gross, D.D.S., Phar.D.
Newton,
Kansas.

Walter F. Graham, B.S.,
Metallurgist,
Henry Souther Engineering Co.
Hartford, Connecticut.

E. B. Tuttle, E.E.,
Engineer of Transmission and Protection,
Bell Telephone Company of Pennsylvania,
Philadelphia, Pennsylvania.

Mr. Charles J. Ramsburg, Vice-president,
The Koppers Company,
Pittsburgh, Pennsylvania.

Augustus Trowbridge, Ph.D.,
Professor of Physics,
Princeton University,
Princeton, New Jersey.;

lectures before the Sections by

Hugh S. Taylor, D.Sc.,
Associate Professor of Physical Chemistry,
Princeton University,
Princeton, New Jersey.

on "Catalysis and Catalytic Agents in Chemical Processes"; by

Colonel E. Lester Jones, A.M., Director,
U. S. Coast and Geodetic Survey,
Washington, District of Columbia.

on " Surveying from the Air";

lecture before the Stated Meeting February 15, 1922, by

> L. J. Briggs, M.S., Ph.D.,
>> Chief of Engineering Physics Division,
>>> Bureau of Standards,
>>>> Washington, District of Columbia.

on " Resistance of the Air";

a series of lectures on the afternoons of March 6th to 10th, inclusive, by

> F. W. Aston, F.R.S., Fellow of Trinity College,
>> Cambridge,
>>> England.

on " Atomic Weights and Isotopes";

and additions to the library by gift, 27 volumes and 102 pamphlets, by purchase, 15 volumes and by binding 76 volumes.

A report of progress was presented by the Committee on Science and the Arts.

The President then announced that the Philadelphia Section of the American Institute of Electrical Engineers was meeting jointly with the Institute and requested Mr. P. H. Chase, Chairman of the Philadelphia Section, to preside during the reading of the paper and its discussion. Dr. M. deKay Thompson, Associate Professor of Electrochemistry, Massachusetts Institute of Technology, Cambridge, Massachusetts, then presented the paper of the evening on " Recent Progress in Applied Electrochemistry." An account was given of the recent progress in the different branches of electroplating, batteries, and the manufacture of numerous substances by electrolysis and electrothermic means. The subject was illustrated by lantern slides.

A unanimous vote of thanks was extended to Doctor Thompson for his interesting paper.

Adjourned.   R. B. Owens.
                                                            Secretary.

COMMITTEE ON SCIENCE AND THE ARTS.

(Abstract of Proceedings of the Stated Meeting held Wednesday, March 1, 1922.)

> HALL OF THE INSTITUTE,
> PHILADELPHIA, March 1, 1922.

Dr. James Barnes *in the Chair.*

The following reports were presented for first reading:
    No. 2783: Interlocking Tooth Saw.
    No. 2787: Literature.

                                                            R. B. Owens,
                                                            Secretary.

SECTIONS.

Section of Physics and Chemistry.—A meeting of the Section was held in the Hall of the Institute on Thursday evening, February 9, 1922, at 8 o'clock. The minutes of the previous meeting were read and approved.

L. J. Henderson, M.D., Professor of Biological Chemistry in Harvard University, Cambridge, Massachusetts, delivered an illustrated lecture on " Applications of Physical Chemistry to the Physiology of Breathing." The respiratory changes in the blood were described; and an account was given of the various factors which control the transport of oxygen and carbon dioxide in the blood stream and produce an extremely complex chemical equilibrium.

The communication was discussed by Dr. Carl Hering, Doctor Henderson, and others. A vote of thanks was extended to Doctor Henderson; and the meeting adjourned.

JOSEPH S. HEPBURN,
Secretary.

Section of Physics and Chemistry.—A meeting of the Section was held in the Hall of the Institute on Thursday evening, February 23rd, at eight o'clock, with Dr. R. B. Owens in the Chair. The minutes of the previous meeting were approved.

Hugh S. Taylor, Sc.D., Associate Professor of Physical Chemistry in Princeton University, Princeton, New Jersey, delivered a lecture on " Catalysis and Catalytic Agents in Chemical Processes." The following subjects were discussed: " The General Features and the Theories of Catalysis and Catalytic Agents," " The Principles and Methods of Research in Problems of Catalysis," " The Form of the Catalyst, Poisons, Promoters," " The Technical Applications of Catalysis." The lecture was illustrated with specimens and with lantern slides. After a lengthy discussion of the communication, a vote of thanks was extended to Doctor Taylor, and the meeting adjourned.

JOSEPH S. HEPBURN,
Secretary.

MEMBERSHIP NOTES.

ELECTION TO MEMBERSHIP.

(Stated Meeting, Board of Managers, March 8, 1922.)

RESIDENT MEMBERSHIP.

Dr. J. L. CRENSHAW, Bryn Mawr College, Bryn Mawr, Pennsylvania.

Mr. ISAAC H. FRANCIS, Otis Building, Philadelphia, Pennsylvania.

Dr. D. H. KABAKJIAN, Department of Physics, University of Pennsylvania, Philadelphia, Pennsylvania.

Mr. THOS. S. ROWLAND, 6311 N. Camac Street, Philadelphia, Pennsylvania.

Mr. E. B. TUTTLE, Bell Telephone Company, 261 N. Broad Street, Philadelphia, Pennsylvania.

Mr. Walter Franklin Graham, 11 Laurel Street, Hartford, Connecticut.

Dr. A. S. Gross, 508½ Main Street, Newton, Kansas.

Mr. C. J. Ramsburg, Koppers Company, Pittsburgh, Pennsylvania.

Prof. Augustus Trowbridge, Princeton University, Princeton, New Jersey.

CHANGES OF ADDRESS.

Colonel P. Junkersfeld, McClellan & Junkersfeld, Inc., 45 William Street, New York City, New York.

Dr. Rudolph Hering, 550 W. 157th Street, New York City, New York.

Mr. I. N. Knapp, 504 Aspen Street, N. W., Tacoma Park, Washington, District of Columbia.

Mr. Howard C. Slater, Ridley Park, Pennsylvania.

Dr. Leslie D. Smith, 406 Rutland Courts, 1725—17th Street, N. W., Washington, District of Columbia.

Mr. J. T. Wallis, Chief of Motive Power, Pennsylvania System, Broad Street Station, Philadelphia, Pennsylvania.

Mr. John Wiegand, 2020 N. Marshall Street, Philadelphia, Pennsylvania.

NECROLOGY.

Charles Baskerville was born on July 18, 1870, at Deer Brook, Mississippi, and died on January 28, 1922, at New York City. His early training was obtained in the Universities of Mississippi, Virginia, Vanderbilt and North Carolina, receiving from the latter the degree of Bachelor of Science, in 1892. The University of Berlin conferred upon him the degree of Doctor of Philosophy in 1893, also the University of North Carolina in 1894. He was instructor in Chemistry, 1891–1894, at the latter institution; Assistant Professor of Chemistry, 1895–1898; Associate Professor of Chemistry, 1898 to 1900, and Professor of Chemistry, 1900 to 1904. In 1904 he accepted the Professorship of Chemistry and the Directorship of the Chemical Laboratories of the College of the City of New York, which positions he held until the time of his death. He was a member of the leading chemical societies of this country and Europe and was also connected with many of the other technical and scientific organizations. In addition to nearly two hundred papers which he published in the scientific and technical press since 1893, the following are the more important of his books:

" School Chemistry and Key," 1898.

" Radium and Radioactive Substances. Their Application Especially to Medicine," 1905.

" General Inorganic Chemistry," 1909.

" Laboratory Exercises to be Used with General Inorganic Chemistry" (with R. M. Curtis), 1909.

" Course in Qualitative Chemical Analysis " (with L. J. Curtman), 1910.

" Progressive Problems in General Chemistry " (with W. L. Estabrooke), 1910.

" Anæsthesia " (with J. T. Gwathmey), 1914.

He was also editor of " Municipal Chemistry," published in 1911.

Doctor Baskerville became a member of The Franklin Institute on July 2, 1904. He was awarded the Institute's Edward Longstreth Medal in 1912. Few American chemists were more widely known for their contributions both in the fields of pure and applied science and as a successful teacher. He was possessed of a peculiar personal charm that will always be remembered by those, and there were many, fortunate enough to know him.

Dr. William Frear, whose death occurred at State College, Pennsylvania, on January 7, 1922, was born at Reading, Pennsylvania, in 1860. His father was a clergyman. He was educated at Bucknell University, receiving therefrom in 1881 the degree of Bachelor of Arts. In 1883 he received his doctorate from Wesleyan University of Illinois. He began teaching as soon as he had finished his course at Bucknell, and was for several years associated with the Natural Science Department of that Institution. From there he went to the Department of Agriculture of the United States, serving for two years as an assistant chemist. This gave him the definite direction for his life work, and in 1885 he was appointed assistant professor of Chemistry at Pennsylvania State College. Two years later he became full professor, serving until 1908. The extensive development of experiment station work and the concentration of such at the State College caused his transfer to research work and to the administration of the fertilizer control which was established under the State Law. In this field he was active for many years, during which he took part in the work of the State Board of Agriculture.

The control of the food supplies of Pennsylvania was first undertaken by the State Board of Agriculture, and much of the work was done in connection with State College, so that Doctor Frear was actively concerned with this line. Later the organization of the Association of Official Agricultural Chemists brought him into direct relation with the development and investigations of the methods of analysis, intended to secure accuracy and uniformity in the examination of foods. Subsequently, the Pennsylvania food control was placed under a definite bureau with which Doctor Frear was associated from 1895 on.

Doctor Frear devoted himself with great assiduity to the fields to which he was assigned, and enriched agricultural and food chemistry with many important researches among which are studies of the culture of tobacco, of the composition of commercial vinegars and breakfast foods, effects of lime in fertilizers, digestibility of cattle foods, proximate composition of forage plants, soil acidity and the composition of Pennsylvania limestones. He was a member of many societies for the promotion of knowledge of chemistry and agriculture, including the Deutsche Chemische Gesellschaft.

Personally, Doctor Frear was an agreeable, companionable gentleman, ever ready to advise upon matters with which he was familiar, and very earnest in the pursuit of the problems which lay before him. During his too short life, he enriched chemistry as applied to agriculture and to food control with many valuable discoveries, and his loss will be deeply felt in these fields.

HENRY LEFFMANN.

John C. Pennie was born in Albany, New York, on August 29, 1858, and died in New York City on December 23, 1921. He was educated in the public schools of his native city, and in 1874 entered Union College, from which he was graduated in June, 1877, with the degree of Civil Engineer and Bachelor of Arts. He then attended the Albany Law School where he obtained the degree of Bachelor of Laws and concluded his legal studies at the Universities of Breslau and Göttingen. On his return to this country Mr. Pennie was admitted to the bar of the State of New York, but decided to devote himself to patent practice and accepted a position as assistant examiner in the Patent Office. Two years later he resigned his position and entered upon the practice of law, removing his office in 1904 to New York City, where he has since been active. In 1919 he was elected as the advisor on Patent Matters of the American Commission to Negotiate Peace and spent six months in Paris. For his services in this connection he was made a Commander of the Crown by King Albert of Belgium.

Mr. Pennie became a member of The Franklin Institute on July 3, 1889.

William Henry Richmond was born at Marlborough, Hartford County, Connecticut, on October 23, 1821, and died at Daytona, Florida, on March 14, 1922. Mr. Richmond was educated in the Marlborough and Middle Haddam, Connecticut, public and private schools. He spent from his thirteenth to his sixteenth years in business, but resumed his studies in 1837 continuing to 1842. In 1860 he first began the mining of coal in Blakeley Township near Scranton, Pennsylvania, and erected one of the first coal breakers on the Delaware and Hudson Canal.

Mr. Richmond was a director in a number of banking concerns and was a member of the leading technical societies. He became a member of The Franklin Institute in December, 1912.

Mr. Wm. C. Carnell. 1141 Arrott Street, Frankford, Philadelphia, Pennsylvania.

Mr. Frank H. Clement, Land Title Building, Philadelphia, Pennsylvania.

LIBRARY NOTES.

PURCHASES.

American Institute of Chemical Engineers, *Transactions 1918*. 1920.
BOLTON, L.—Introduction to the Theory of Relativity. No date.
CAMPBELL, NORMAN R.—Physics of the Elements. 1920.
GAGE, SIMON HENRY.—The Microscope. 1920.
HALE, HARRISON.—American Chemistry. 1921.
KIDDER, FRANK E.—Architects' and Builders' Handbook. 1921.
MARTIN, MARCUS J.—Electrical Transmission of Photographs. 1921.
MERCER, J. E.—Alchemy, its Science and Romance. 1921.
Photograms of the Year. 1921.

SCOTT-TAGGART, JOHN.—Thermionic Tubes in Radio-telegraphy and Telephony. 1921.

WALKER, MILES.—Diagnosing Troubles in Electrical Machines. 1921.

ZIPSER, JULIUS.—Textile Raw Materials and Their Conversion into Yarns. 1921.

GIFTS.

Adamson, Daniel, and Company, Ltd., Cheap Power and Compressed Air. Dukinfield, England, no date. (From the Company.)

Alfred College, Catalogue 1921–1922. Alfred, New York, 1921. (From the College.)

Allen, Edgar, and Company, Ltd., Saw Service. Sheffield, England, 1921. (From the Company.)

Allen-Liversidge, Limited, Portable Acetylene Lamps and Country House Lighting. London, England, no date. (From the Company.)

American Institute of Mining and Metallurgical Engineers, Transactions, vol. lxv. New York City, New York, 1921. (From the Institute.)

American Society of Mechanical Engineers, Year Book, 1922. New York City, New York, 1921. (From the Society.)

Amherst College, Catalogue 1921–1922. Amherst, Massachusetts, 1921. (From the College.)

Armature Coil Equipment Company, Superior Coil Winding Machine. Cleveland, Ohio, no date. (From the Company.)

Armour and Company, Catalogue for 1922. Chicago, Illinois, 1921. (From the Company.)

Beldam Packing and Rubber Company, Limited, Catalogue of Engine Packings, etc. Brentford, Middlesex, England, 1921. (From the Company.)

Blackman Export Company, Limited, Air Heaters and Washers. London, England, 1921. (From the Company.)

Blackstone and Company, Limited, Publication 243 on Oil Engines. Stamford, England, 1921. (From the Company.)

Brett Patent Lifter Company, Limited, General Catalogue of Brett Drop-forging Equipments. Coventry, England, 1921. (From the Company.)

Bristol Company, Preliminary Catalogue No. 1501. Waterbury, Connecticut, 1921. (From the Company.)

Bryant Electric Company, Superior Wiring Devices. Bridgeport, Connecticut, 1920. (From the Company.)

Canadian Car and Foundry Company, Limited, Bulletins 11, 12, 13, 21, 22, 23, 24, 25, 26, 31, 41, 42 and 43. Montreal, Canada, no date. (From the Company.)

Carter Bloxonend Flooring Company, Pamphlet of Bloxonend Flooring. New York City, New York, no date. (From the Company.)

Central Scientific Company, Catalogue E. Chicago, Illinois, 1920. (From the Company.)

Cole, Marchent and Morley, Ltd., Catalogue of Coal Consumption. Bradford, Yorks, England, 1921. (From the Company.)

Colorado School of Mines, Catalogue. Golden, Colorado, 1922. (From the School.)

Columbia University, Summer Session Announcement, 1922. New York City, New York, 1922. (From the University.)

Cooke, T., and Sons, Limited, Direct Reading Tacheometer and Surveying and Other Scientific Instruments. London, England, no date. (From the Company.)

Crafts, Arthur A., and Company, Diamonds Used in Tools. Boston, Massachusetts, no date. (From the Company.)

Dartmouth College, Catalogue 1921–1922. Hanover, New Hampshire, 1921. (From the College.)

Direct Separator Company, Catalogue 19 of Steam and Oil Separators. Syracuse, New York, 1921. (From the Company.)

Donovan and Company, Safuse and Donlok Gears. Birmingham, England, 1921. (From the Company.)

Dorr Company, Testing that Pays Dividends. New York City, New York, no date. (From the Company.)

Duncan Stewart and Company, Limited. Catalogue of Billet, Plate and Slab Shears. Glasgow, Scotland, 1921. (From the Company.)

Dunham, C. A., Company, Bulletin 109 of Return Heating System. Chicago, Illinois, 1921. (From the Company.)

Dust Recovering and Conveying Company, Bulletins 502, 505, 506 and 1001. Cleveland, Ohio, 1921. (From the Company.)

Eastern Machine Screw Corporation, Die Heads. New Haven, Connecticut, 1921. (From the Corporation.)

Eck Dynamo and Motor Company, Bulletins 1300, 1600 and 1900. Belleville, New Jersey, 1921. (From the Company.)

Electric Storage Battery Company, Catalogue of Exide Batteries, Section SLP. Philadelphia, Pennsylvania, 1922. (From the Company.)

Esterline-Angus Company, Bulletins 122 and 222. Indianapolis, Indiana, 1921. (From the Company.)

Foster Instrument Company, Book 26 of Practical Pyrometers and Book 23 of Radiation Pyrometry. Letchworth, Herts, England, 1921. (From the Company.)

Goulds Manufacturing Company, Bulletin 123 of Goulds Pumps. Seneca Falls, New York, 1921. (From the Company.)

Gray, The G. A., Company, Gray Planers. Cincinnati, Ohio, 1921. (From the Company.)

Harbour Improvement and Mechanical Engineering Company, Limited, Cranes and Hoisting Machinery. London, England, 1921. (From the Company.)

Hardinge Company, Catalogue 12 of Quigley Fuel Systems. New York City, New York, 1922. (From the Company.)

Harvard College Astronomical Observatory, Annals, vol. 96. Cambridge, Massachusetts, 1921. (From the Observatory.)

Harvey, G. A., and Company, Limited, Catalogue of Chimneys. London, England, no date. (From the Company.)

Hayward Company, Hayward Buckets, Catalogue 43. New York City, New York, 1916. (From the Company.)

Higgs Brothers, Electric Motor Specification No. 7. Birmingham, England, 1921. (From the Company.)

Shannon, J. Jacob, and Company, Catalogue of Derricks, Engines and Equipment. Philadelphia, Pennsylvania, no date. (From the Company.)

Siemens Brothers and Company, Limited, Pamphlets A701, 702A, B705, 709A, A720 and 730A. Woolwich, England, 1921. (From the Company.)

Simon-Carves, Limited, Catalogue A.P. 3 and 4. Manchester, England, no date. (From the Company.)

Skinner Chuck Company, Skinner Chucks and Chucks and Their Uses. New Britain, Connecticut, 1920. (From the Company.)

Smith College, Catalogue 1921–1922. Northampton, Massachusetts, 1921. (From the College.)

Smith, Thomas, Stamping Works, Limited, Drop Forgings Plus Service. Coventry, England, no date. (From the Works.)

Spencer-Bonecourt, Limited, Modern Steam Generation. London, England, 1921. (From the Company.)

Steam Fittings Company, Limited, Automatic Temperature Regulation. West Drayton, England, 1921. (From the Company.)

Stebbins, E., Manufacturing Company, Catalogue of Brass Goods. Springfield, Massachusetts, 1922. (From the Company.)

Stockton and Bunn, Limited, Casehardening Compounds. London, England, no date. (From the Company.)

Sturtevant, B. F., Company, Bulletin 246, Generator Cooling Apparatus. Hyde Park, Boston, Massachusetts, 1921. (From the Company.)

Sullivan Machinery Company, Bulletins 70W, 71F and 71G. Chicago, Illinois, 1921. (From the Company.)

Taylor, J. Norman, and George W. Phillips, Nitrogen in the Arts and Industries. New York City, New York, 1921. (From Dr. Charles E. Munroe.)

Ternstedt Manufacturing Company, Catalogue 2 of Automobile Body Hardware. Detroit, Michigan, no date. (From the Company.)

Thor Electric Safety Lamp Company, Limited, Circular of " Thor " Miners' Lamp. Birmingham, England, no date. (From the Company.)

Tiffin Wagon Company, Motor Trucks and Street Sprinklers. Tiffin, Ohio, no date. (From the Company.)

Triplex Machine Tool Corporation, Catalogue No. 1 of Machine Tools. New York City, New York, no date. (From the Corporation.)

Union Mining Company, Catalogue H, Pertaining to Fire Brick. Baltimore, Maryland, 1921. (From the Company.)

United Fruit Company, Twenty-second Annual Report. Boston, Massachusetts, 1921. (From the Company.)

United States Electric Company, Bulletin No. 6. New London, Connecticut, no date. (From the Company.)

United States Geological Survey, Mines Report for 1919, and Bulletin 726G. Washington, District of Columbia, 1922. (From the Director.)

United States Naval Observatory, American Ephemeris and Nautical Almanac for 1924. Washington, District of Columbia, 1921. (From the Observatory.)

University of Maine, Catalogue 1921–1922. Orono, Maine, 1921. (From the University.)

University of Michigan, Catalogue 1920–1921. Ann Arbor, Michigan, 1921.
(From the University.)

University of Missouri, Bulletin: The Problem of the St. Peter Sandstone.
Rolla, Missouri, 1921. (From the University.)

University of Pennsylvania, Catalogue 1921–1922. Philadelphia, Pennsylvania,
1921. (From the University.)

University of Rochester, Catalogue 1921–1922. Rochester, New York, 1921.
(From the University.)

V. and O. Press Company, Catalogue of Presses. Brooklyn, New York, 1921.
(From the Company.)

Welch, W. M., Scientific Company, Catalogue of Direct Current Meters.
Chicago, Illinois, no date. (From the Company.)

Wellman Smith Owen Engineering Corporation, Limited, Catalogue of Charg-
ing Machines. London, England, 1921. (From the Corporation.)

Western Australia Geological Survey, Bulletins 78, 79, 80 and 81. Perth,
Western Australia, 1921. (From the Government Geologist.)

BOOK NOTICES.

COLLECTED PAPERS ON ACOUSTICS. By Wallace Clement Sabine, late Hollis
Professor of Mathematics and Natural Philosophy in Harvard University.
279 pages, illustrations, plates, portrait, quarto. Cambridge, Harvard Uni-
versity Press, 1922. Price $4.00.

One of the blessings that the art of printing has conferred is that of provid-
ing in convenient form a permanent record of the work done by the scientific
investigator. Such a record is of great value, not only to other investigators
in the same field but to those who wish to know the steps by which the science
or the art has reached its present development.

Professor Sabine's investigations in the field of applied acoustics, which
are covered in this series of papers, were begun in 1895 when he was requested
by the Corporation of Harvard University to propose changes in the lecture
room of the Fogg Art Museum that would remedy defects in its acoustic proper-
ties. He spent two years in making these investigations and the result obtained
did much to remove the chaotic condition of our knowledge of practical acoustics.

Professor Sabine recognized three requirements for good hearing in an
auditorium that is itself good. The sound should be sufficiently loud, the
simultaneous components of a complex sound should maintain their relative in-
tensities and the successive sounds in rapid articulation should be clear, distinct
and free from each other and from disturbing noises.

These, however, have to do with the production of sound and not with its
transmission to the ear of the hearer. When this part of the problem is con-
sidered its requirements cannot be stated in such a simple form. If an audience
room is built that is a replica of one known to have good acoustic qualities
the builder cannot be sure that the hearing will be as good as it is in the
original room. Some, apparently minor, detail has been omitted perhaps and
this omission has entirely changed its character as an auditorium.

Professor Sabine set himself to the problem of finding out the effect of
all that enters into the construction of an audience room upon its acoustic

qualities and in order to get measurable results he constructed models in which he could make changes and find the results of each.

One has but to read the table of contents of this book to see how thoroughly both the theoretical and practical side of sound have been covered in this group of papers extending from that on " Reverberation" published in the *American Achitect* for 1900 to that on the " Insulation of Sound " published in the *Bricklayer* for 1915.

Since the eleven papers included in the series are founded on lectures or papers delivered before scientific bodies over a series of years, a certain amount of repetition was to be expected.

Probably the most complete summary of Professor Sabine's Work is contained in the paper presented before The Franklin Institute in 1914 and printed in the JOURNAL OF THE INSTITUTE in 1915.

Professor Sabine's reputation in the field of acoustics is international as is evidenced by the lectures given by him at the Sorbonne in 1917. It is to be regretted these lectures were never prepared for publication in full.

GEO. A. HOADLEY.

THE VITAMINS. By H. C. Sherman, Professor of Food Chemistry, Columbia University, and S. L. Smith, Specialist in Biological and Food Chemistry in the United States Department of Agriculture. American Chemical Monograph Series. 234 pages, bibliography, index, illustrations and plates, 8vo. New York, The Chemical Catalog Company, 1922. Price, $4.00.

The literature of the vitamins has grown with great rapidity, and their uses have been exploited in both the scientific and popular fields. As might be expected, the charlatan has utilized the general interest to secure profit, and the columns of newspapers and non-scientific journals have been extensively occupied with statements of claims more or less exaggerated as to the value of certain foods. It is gratifying, therefore, to have in a compact form a selection of the trustworthy data. Though much of the information set forth is comparatively new, we find, as might be expected, some of the principles foreshadowed many years ago. From the useful and interesting historical note we learn that as early as 1720 it was pointed out that certain fresh vegetables and fruit juices would relieve scurvy which resisted all the usual means of medicine and surgery. The long sea voyages which began to be common after the discovery of America, and the ability to circumnavigate the globe caused scurvy to become a most serious source of disability, and during the eighteenth century, the British navy, which then controlled the seas, as it has done since, found this disease a source of high fatality. In 1804, the issue of a ration of lemon juice was made compulsory in this navy, and the disease became quite rare. The shorter voyages that are now common, owing to the introduction of steam, have rendered such precautions of less importance, but sailing vessels are still under the rule.

The general subject of the vitamins is too well known to chemists to require much statement here. The Historical Introduction gives the main items of discovery and investigation, by which the three forms now recognized have been indicated, that is the fat-soluble A, and water-soluble B and C. The term itself is somewhat of misnomer, apparently as at least some of the

substances are not amin derivatives. It will, doubtless, have to stand until the real structural formulas are discovered. A very large portion of the information regarding the three forms and their occurrence has been derived from feeding experiments on lower animals. These have been extremely numerous and the patience and care with which the work has been carried out merit high appreciation of all interested in food questions. One of the most important questions in practical food hygiene is the effect of heating milk. Control of the milk supply of a city is a very difficult problem. The country districts from which the supply comes are often far from being in good sanitary condition, and the methods of collecting, transporting and distributing are all sources of serious contamination. It has, therefore, seemed to municipal experts that sterilization or pasteurization will be satisfactory, as the greater part of the living organisms will be killed. It is now, however, generally admitted that sterilization is unwise, and it has been thought that equally good results as to cleaning the milk, without injuring its nutritive value appreciably, can be secured by heating to a lower temperature. For this reason the milk supplies of some cities are all pasteurized. Experiments, however, show that it is possible by such methods to injure materially the activity of the vitamin C, known as the anti-scorbutic vitamin. This exists in the watery portion of the milk, and may be injured by even pasteurization processes, so that children fed on such milk will fare but poorly. It is stated that the injury to the vitamin is partly due to oxidation; at least, pasteurization in a closed container does not produce as much injury as when the mass of milk is allowed to flow over a heated surface. Milk, by the way, as might be expected, contains all known vitamins. It appears from some clinical experiences that, so far as human beings are concerned, the growing animal is much more sensitive to lack of vitamins than the well-developed adult.

The work before us must be judged in two aspects: First, as to its merit as a member of the series, and second, as a contribution to the field to which it is devoted. In both aspects it deserves high praise. Its methods, form and general make-up maintain the character of the works of the series already published, and the authors have given full attention to the extensive literature as well as worked assiduously themselves in adding to the store of knowledge. The present available data on the question of vitamins, drawn so largely from experiments on the lower animals, will have to be subjected to the tests of wide clinical experience, before they can be regarded as fully established. In a review some years ago of a book by the senior author of the volume now in hand, the present reviewer postulated the query as to whether it was safe to attempt to reduce the human dietary to a mere matter of calories. The development of the vitamin theory seems to answer the question in the negative. All these problems are so complex that inferences must be considered tentative.

In the case of rickets, for instance, it has been shown that exposure to sunlight may overcome the effects of certain deficiencies of diet, and hence as stated by Hess, Unger and Pappenheimer in a recent publication (*J. Biol. Chem.*, vol. 50, 77) the illumination factor must always be taken into account. Sufficient has been said to show the excellence of the work of Messrs. Sherman and Smith. As a piece of book-making the volume is quite up to the best standards. It appears from a recent German review of one of the

books of this series that German scientists are not pleased at the method
and earnestness with which Americans are building up an independent literature
in these fields. To this the American can only say, " Let the stricken deer
go weep." HENRY LEFFMANN.

AN INTRODUCTION TO THE PHYSICS AND CHEMISTRY OF COLLOIDS. By Emil
Hatschek. Fourth edition, entirely rewritten and enlarged. 12mo., 165
pages, contents, index and 30 illustrations. Philadelphia, P. Blakiston's
Son and Company. Price, $2.25 net.

Hatschek's compact and interesting manual has been so long favorably
known to those interested in physical chemistry, that this edition would seem
to require no notice other than to announce its publication. The present
volume is about double the size of the first edition, and records the present
state of colloidal chemistry, the literature of which is growing at a very rapid
rate. It seems occasionally to those not immersed in such studies, that the
field has a sort of hypnotic influence over its votaries. They see colloids in
every part of nature, from blue eyes to blue sky. The extensive work of one
of the European authorities on the subject seems to indicate that he is prepared
to hold the view that the primordial chaos was a colloid and the fiat of
creation was a flocculation of it. The work now in hand can be recommended
as a highly satisfactory introduction to the study of this important field.
It has been largely rewritten, but some of the original matter remains. The
illustration of ultramicroscope is the same as used in the first edition, and
as there is little doubt that a fifth edition will be called for, it would be well
to revise and extend somewhat this part of the book, presenting in some detail
the later designs in apparatus for the observation of minute particles. The
reference on page 14 to the fact that sand filters retain bacteria, although
these organisms are much smaller than the interstices of the grains, is not
opportune, as filtration engineers have shown that the retaining power of a slow
sand filter is dependent on a growth of bacterial colonies, mostly in the upper
layer of the sand, but partly deeper. It is this which acts as the retaining
agent, and until such a filter is " ripe," that is, has formed this layer, it has
low efficiency. HENRY LEFFMANN.

NATIONAL ADVISORY COMMITTEE FOR AERONAUTICS. Report No. 123, Simplified
Theory of the Magneto. By F. B. Silsbee, Bureau of Standards. 15
pages, illustrations, plate, quarto. Washington, Government Printing
Office, 1922.

This paper contains part of the results of ignition investigations being
made for the National Advisory Committee for Aeronautics at the Bureau of
Standards, and describes a type of circuit which has been found useful for
representing the action of the high-tension magneto. While this equivalent
circuit is relatively simple, and consequently can be used as a basis for deriving
definite mathematical formulas for induced voltages and similar quantities, it
has been found experimentally to correspond quite closely in its performance
with the highly complicated electrical circuits of an actual magneto. In the
paper formulas are given for the voltage induced in the secondary under various
conditions of operation, and a number of numerical examples are worked
out showing the application of the equations to a variety of practical problems.

PUBLICATIONS RECEIVED.

Collected Papers on Acoustics, by Wallace Clement Sabine, late Hollis Professor of Mathematics and Natural Philosophy in Harvard University. 279 pages, illustrations, portrait, quarto. Cambridge (Mass.), *Harvard University Press,* 1922. Price, $4.00.

The Vitamins, by H. C. Sherman, Professor of Food Chemistry, Columbia University, and S. L. Smith, Specialist in Biological and Food Chemistry, United States Department of Agriculture. American Chemical Society Monograph Series. 273 pages, illustrations, 8vo. New York, The Chemical Catalog Company, Inc., 1922. Price, $4.00 net.

Practical Electrical Engineering. Direct Currents. A manual for use in industrial and evening schools and for home study, by Harry G. Cisin, M.E., Engineering Editor, *Electrical Record.* 324 pages, illustrations, 12mo. New York, D. Van Nostrand Company, 1922. Price, $2.00.

Elements of the Differential and Integral Calculus with Applications, by William S. Hall, E.M., C.E., M.S., Professor of Mathematics in Lafayette College. Second edition, revised. 250 pages, illustrations, 8vo. New York, D. Van Nostrand Company, 1922. Price, $2.75.

Éther ou Relativité, par Maurice Gandillot. 84 pages, 12mo. Paris, Gauthier-Villars et Cie., 1922. Price, 4 francs 50.

La Théorie de la Relativité et ses Applications a l'Astronomie, par Emile Picard, Secrétaire Perpétuel de l'Académie des Sciences. 27 pages, 12mo. Paris, Gauthier-Villars et Cie., 1922.

L'Éther Actuel et ses Précurseurs (Simple Recit), par E. M. Lémeray. Préface de L. Lecornu, Membre de l'Institut. 141 pages, 12mo. Paris, Gauthier-Villars et Cie., 1922.

Carnegie Institution of Washington: Researches of the Department of Terrestrial Magnetism, volume iv. Land Magnetic Observations 1914–1920, by L. A. Bauer, J. A. Fleming, H. W. Fisk and W. J. Peters and Special Reports. J. A. Fleming: Construction of Non-magnetic Experiment Building of the Department of Terrestrial Magnetism. H. W. Fisk: Dip-needle Errors Arising from Minute Pivot-defects. S. J. Barnett: A Sine Galvanometer for Determining in Absolute Measure the Horizontal Intensity of the Earth's Magnetic Field. J. A. Fleming: Results of Comparisons of Magnetic Standards, 1915–1921. 475 pages, illustrations, plates, quarto. Washington, Carnegie Institution, 1921.

American Telephone and Telegraph Company: Annual Report of the Directors to the Stockholders for the Year Ending December 31, 1921. 44 pages, illustrations, 8vo. New York, Company, 1922.

Fundamentals of Economical Plumbing: Being Suggestions Made in June, 1921, to Secretary Hoover's National Building Code Committee in the Interest of the Betterment of the Housing Situation by Wm. Paul Gerhard, C.E., Dr. Eng. 4 pages, quarto. Reprinted from *The American Architect— The Architectural Review,* December 21, 1921. Price, 30 cents.

Sanitation and Sewage Disposal for Farmsteads and County Estates, by William Paul Gerhard, C.E., Dr. Eng., Consulting Engineer, Member, American Public Health Association. 12 pages, 8vo. New York, Author, no date. Price, 30 cents.

National Advisory Committee for Aeronautics: Technical Notes, No. 83,
The Theory of the Screw Propeller, by A. Betz. Reprinted from *Die Natur-
wissenschaften*, 1921, No. 18. 12 pages, illustrations, quarto. No. 84, New
Data on the Laws of Fluid Resistance, by C. Wieselsberger. Taken from
Physikalische Zeitschrift, 1921, vol. 22, 12 pages, illustrations, quarto. No. 85,
Air Force and Three Moments for F-5-L Seaplane by the Aeronautics Staff,
Construction Department, Navy Yard, Washington, D. C. 13 pages, quarto,
No. 88, Surface Area Coefficients for Airship Envelopes, by W. S. Diehl,
Bureau of Aeronautics, U. S. N. 5 pages, illustrations, quarto. Washington,
Committee, 1922.

Paving Costs. (*U. S. Department of Agriculture Press Service
No. 195.*)—Average costs per square yard of various types of paving
for country roads have been compiled by the Bureau of Public
roads, United States Department of Agriculture. The figures cover
68,000,000 square yards of paving constructed with Federal aid in
all parts of the United States during the period 1916–1921. The
costs per square yard are as follows: Sand-clay, 18 cents; gravel, 46
cents; plain and surface-treated macadam, 95 cents; bituminous
macadam, $2.10; bituminous concrete, $2.50; plain cement concrete,
$2.57; reinforced-cement concrete, $2.74; and brick, $4.10.

These figures cover only the cost of the paving; they do not
include the cost of grading, and officials point out that it must not be
assumed that roads of the several types can be constructed in any
locality at these figures. For example, the cost of bituminous con-
crete varied from $1.70 in the New England States to $3.13 in the
group of States including Kentucky, Tennessee, Mississippi, and
Alabama. In one group of States the cost of brick dropped to $2.40.
Costs of constructing these types in the various groups of States
have been compiled and can be obtained from the Bureau.

Railroad Ties and Weather Reports. (*U. S. Department of
Agriculture Press Service No. 195.*)—The relationship between rail-
road ties and weather reports would seem to be rather distant, but a
report received by the Weather Bureau of the United States Depart-
ment of Agriculture from one of the large railroad systems of the
West shows that the rainfall charts prepared by the Bureau saved this
railroad a large amount of money.

During the war this road was unable to get creosote and had to
substitute zinc chlorid as a preservative for ties. The zinc salt is
a satisfactory preservative in dry climates, but where the rainfall is
heavy it leaches out. When the war ended this company had on
hand 2,500,000 ties that had been given the zinc treatment. Instead
of re-treating them with creosote, the engineers secured a Weather
Bureau chart and transferred the lines of average precipitation to a
map of the system. Then they distributed the zinc-treated ties for
use on those parts of the road in relatively dry regions.

CURRENT TOPICS.

Dispersion in Water of Electrical Waves of Lengths from 1240 to 600 mm. K. IWANOW, Sofia. (*Ann. d. Physik*, No. 14, 1921.)—Using a method devised by A. R. Colley the author determined the indices of refraction of electric waves in water. By means of a special type of vibrating system the waves are set up. The positions of the nodes, both in air and in water, were determined by a Geissler tube and from them the wave-lengths and the corresponding indices were calculated. We are accustomed to seeing the value of the index given as about 1.33, while in this paper its value lies in the vicinity of 9, but it should be remembered that the waves here employed are much longer than those of the visible spectrum. Colley had previously discovered a range of wave-lengths from 600 to 666 mm. in air through which the index does not change. Iwanow has found an additional range with the same characteristic, from 1188 to 1240 mm. The indices are respectively 8.974 and 8.998. Expressed in a different way this means that these two groups of waves, one of which is twice as long as the other, have about the same speed in water, just as red and violet light have the same speed in air or vacuo in spite of their travelling through glass or water with different speeds.

When light of the visible spectrum passes through a glass prism the red has the greatest speed and the speed grows less in going from one color to another toward the violet. Any such regularity of change is, however, lacking with the waves now under consideration. From 1240 to 1188 mm. wave-length there is no change of speed, as has been said, *i.e.,* the index of refraction does not vary. Then with a slight decrease of wave-length there comes a sudden lowering of speed which is succeeded by an equally abrupt increase which continues until a greater amount than the first is reached. Then there come decreases and increases quite regularly spaced until seven such variations have manifested themselves. After this still further toward smaller wave-lengths there comes an irregular set of increases and decreases until 660 mm. is attained, where for a range to 600 mm. the speed remains constant. Such optical comportment indicates anomalous dispersion, such as is produced by sending light through a prism of fuchsine, where the violet is less deviated than the red. In the case of cyanine R. W. Wood has found a variation of index similar to those described in the case of water. Drude had long ago discovered anomalous dispersion in the case of certain liquids. The effect of changes of temperature on the index of refraction also was investigated. As temperature goes up the index goes down. For example, for a wave-length of 630 mm. in air the

value of the index at 4° C. is 9.3 and at 90 C. is 7.56—no inconsiderable change.

These investigations were carried out at the University of Warsaw before the war. In making his acknowledgments to A. R. Colley, whom he designates as "this talented physicist and my best friend," the author adds that "he died a terrible death as a victim of civil war."

<div style="text-align: right">G. F. S.</div>

Polarization Phenomena in X-Ray Bulbs. S. RATNER. (*Phil. Mag.*, January, 1922.)—"In the course of some experiments with an X-ray bulb through which a continuous discharge was maintained for a long time, the writer has observed a gradual hardening of the bulb in spite of the maintenance of a comparatively high pressure. Further experiments carried out in this direction have revealed a remarkable effect which takes place in an X-ray bulb or, more generally, in any vacuum tube after a sufficiently long and constant run. This is, that after a discharge has been kept running long enough, a time arrives where the resistance of the bulb begins to increase gradually, and finally becomes sufficiently high to stop the discharge altogether, although the pressure remains constant and comparatively high. This phenomenon is somewhat analogous to the polarization of an electrolytic cell." The time required to polarize a tube was in one case a small multiple of twenty-four hours. Then a potential difference of 50,000 volts caused no discharge in the tube though the pressure was as high as .035 mm. "A few hours later the minimum pressure at which the same potential difference could produce a discharge was of the order of .060 mm." Upon reversing the direction of the current it passed readily through the polarized bulb. Left to itself over night a polarized bulb by morning had become normal.

Now as to the causes of the polarization. The gases in the tube are not responsible, for when air is introduced into a polarized tube the phenomenon persists, and the effect develops even while a tiny stream of air is admitted during the passage of the discharge. Even more convincing is the fact that, after polarization has set in, a much lower voltage will cause a discharge between a pair of electrodes in a side tube where the gases present are of necessity the same as in the main tube. The introduction of a little water vapor will promptly reduce the polarization. The author sums up thus: "Now, internal changes in the electrodes could hardly be caused by the discharge, and it seems more likely that the phenomenon is due to the destruction by electronic action of the gaseous layers in the surface of the electrodes. These layers, whose existence is now well established, play an important part in various phenomena. It has long been well known that gases occluded in the electrodes greatly facilitate the passage of a discharge through a vacuum tube, and it has

been found recently that metal surfaces carefully freed from gases do not exhibit any appreciable photo-electric effect. It seems therefore, as if the process of electronic emission from cold metal surfaces could take place only through the intermediary of the surface-layer of gaseous molecules."   G. F. S.

Wider Highway Tendency Shown in Road Building. (*U. S. Department of Agriculture Press Service No. 194.*)—Of 6500 miles of completed Federal-aid road for which statistics have been collected by the Bureau of Public Roads, United Stats Department of Agriculture, one-half has been constructed of 16 and 18-foot width, 25 per cent. of a greater width, and 25 per cent. of a less width. As would be expected the wider roads have been constructed largely in the more populous States, although some of the less populous States are building wider roads for the main highways. There is a general tendency, it is said, to build wider roads to meet the needs of the constantly increasing traffic, as shown by the 25 per cent. of the mileage over 18 feet in width, 7 per cent. being 24 feet or wider.

Wider Bridges for Roads. (*U. S. Department of Agriculture Press Service No. 193.*)—Few highway bridges with a width of roadway less than 18 feet are now being constructed on improved roads, according to engineers of the Bureau of Public Roads of the United States Department of Agriculture. In the past some of 12 feet and a good many of 16-foot width have been constructed in an effort to economize but it has proved short-sighted economy. Only one line of traffic can pass over a 12-foot roadway and 16 feet of width will not accommodate two lines in safety. Many of the States such as Pennsylvania, New Jersey, Ohio, and Massachusetts have found it advisable in replacing old bridges on important roads to make them wide enough to accommodate three and four lines of traffic.

ATOMIC WEIGHTS AND ISOTOPES.*

BY

F. W. ASTON, M.A., D.Sc., F.R.S.

Fellow of Trinity College Cambridge.

THAT matter is discontinuous and consists of discrete particles is now an accepted fact, but it is by no means obvious to the senses. The surfaces of clean liquids, even under the most powerful miscroscope, appear perfectly smooth, coherent and continuous. The merest trace of a soluble dye will color millions of times its volume of water. It is not surprising therefore that in the past there have arisen schools who believed that matter was quite continuous and infinitely divisible.

The upholders of this view said that if you took a piece of material, lead, for instance, and went on cutting it into smaller and smaller fragments with a 'sufficiently sharp knife, you could go on indefinitely. The opposing school argued that at some stage in the operations either the act of section would become impossible, or the result would be lead no longer. Bacon, Descartes, Gassendi, Boyle and Hooke were all partial to the latter theory, and Newton in 1675 tried to explain Boyle's Law on the assumption that gases were made up of mutually repulsive particles.

The accuracy of modern knowledge is such that we can carry

---

* Summary of a series of lectures given before The Franklin Institute, March 6–10, 1922, see page 712.

out, indirectly at least, the experiment suggested by the old philosophers right up to the stage when the second school is proved correct, and the ultimate atom of lead reached. For convenience, we will start with a standard decimetre cube of lead weighing 11.37 kilograms, and the operation of section will con-

FIG. 1.

Thickness of £1 Note

11th

12th

13th

14th

15th

Yeast

.05 mm.
Human Hair

.001 mm.
Thinnest Wollaston
Wire or Quartz Fibre

Influenza Bacilli

Eye of Nº9 Needle

½ m m.

Cubes 11 to 15 compared with familiar objects to scale.
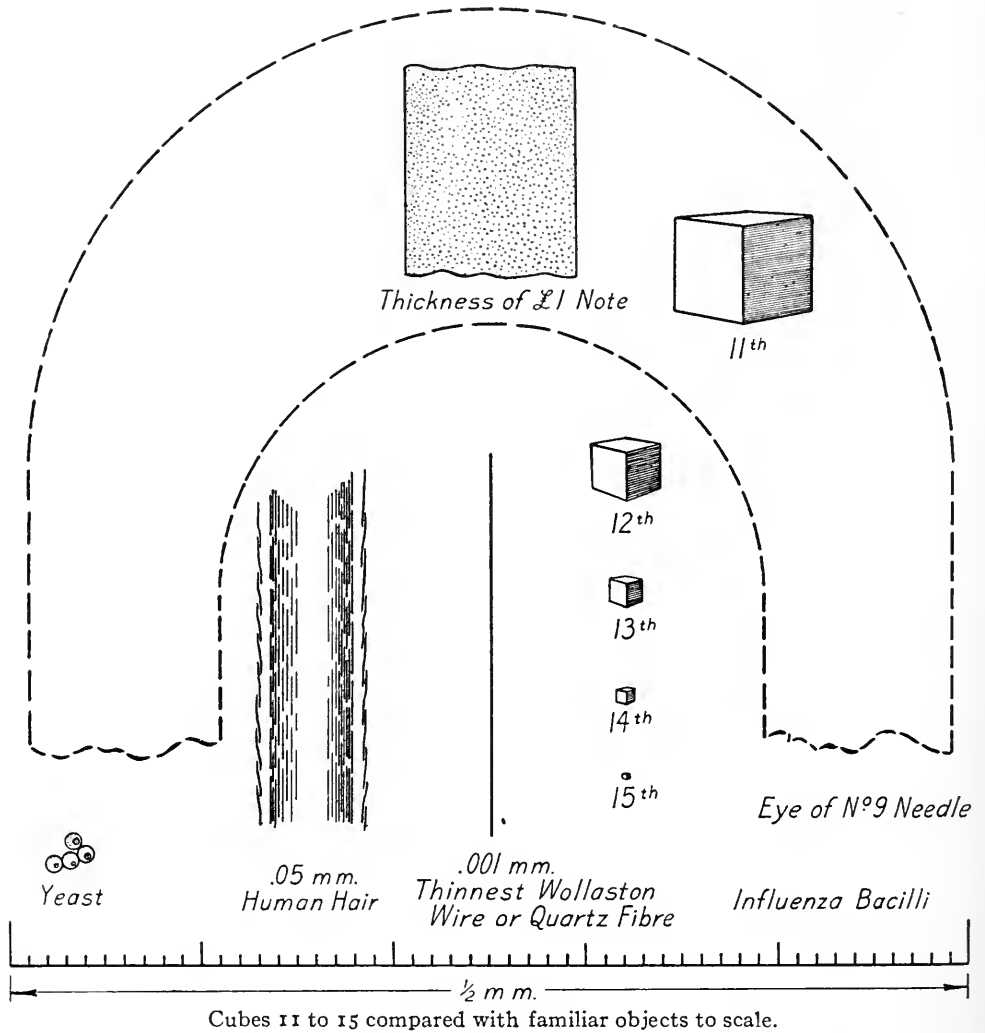
sist of three cuts at right angles to each other, dividing the original cube into eight similar bodies each of half the linear dimensions and one-eighth the weight. Thus the first cube will have 5 cm. sides and weigh 1.42 kilograms, the second will weigh 178 grs., the fourth 2.78 grs. and so on. Diminution in the series is very rapid and the result of the ninth operation is a quantity of lead just weighable on the ordinary chemical balance. The results of further operations are compared with suitable objects

and a scale of length in Figs. 1, 2 and 3. The last operation possible, without breaking up the lead atom, is the twenty-eighth. The twenty-sixth cube is illustrated in Fig. 3. It contains 64 atoms, whose size, distance apart and general arrangement can be represented with considerable accuracy, thanks to the exact knowledge derived from research on X-rays and specific heats. On the same scale are represented the largest atom, cæsium, and the smallest atom, carbon, together with molecules of oxygen and nitrogen, at their average distance apart in the air, and the helical arrangement of silicon and oxygen atoms in quartz crystals discovered by X-ray analysis. The following table shows at what stages certain analytical methods break down. The great superiority of the microscope is a noteworthy point.

Cube.	Side in Cms.	Mass in Grms.	Limiting Analytical Method.
9	.0195	8.5×10^{-8}	Ordinary Chemical Balance
14	6.1×10^{-4}	2.58×10^{-9}	Quartz Micro-balance
15	3.05×10^{-4}	3.22×10^{-10}	Spectrum Analysis (Na lines)
18	3.8×10^{-5}	6.25×10^{-13}	Ordinary Microscope
24	6.0×10^{-7}	2.38×10^{-18}	Ultra Microscope
28	3.7×10^{-8}	5.15×10^{-22}	
Atom.	3.0×10^{-8}	3.44×10^{-22}	Radioactivity

Just as any vivid notion of the size of the cubes passes out of our power at about the twelfth—the limiting size of a dark object visible to the unaided eye—so when one considers the figures expressing the number of atoms in any ordinary mass of material, the mind is staggered by their immensity. Thus if we slice the original decimetre cube into square plates one atom thick the area of these plates will total one and one-quarter square miles. If we cut these plates into strings of atoms spaced apart as they are in the solid, these decimetre strings put end-to-end will reach 6.3 million million miles, the distance light will travel in a year, a quarter of the distance to the nearest fixed star. If the atoms are spaced but one millimetre apart the string will be three and a half million times longer yet, spanning the whole universe.

Again, if an ordinary evacuated electric light bulb were pierced with an aperture such that one million molecules of the air entered per second, the pressure in the bulb would not rise to that of the air outside for a hundred million years. Perhaps the most striking illustration is as follows: Take a tumbler of water and—supposing it possible—label all the molecules in it. Throw the water into the sea, or, indeed, anywhere you please, and after a

period of time so great that all the water on the earth—in seas, lakes, rivers and clouds—has had time to become *perfectly mixed,* fill your tumbler again at the nearest tap. How many of the labelled molecules are to be expected in it? The answer is, roughly, 2000; for although the number of tumblers full of

FIG. 2.

Cubes 17 to 21 compared with minute objects to scale.
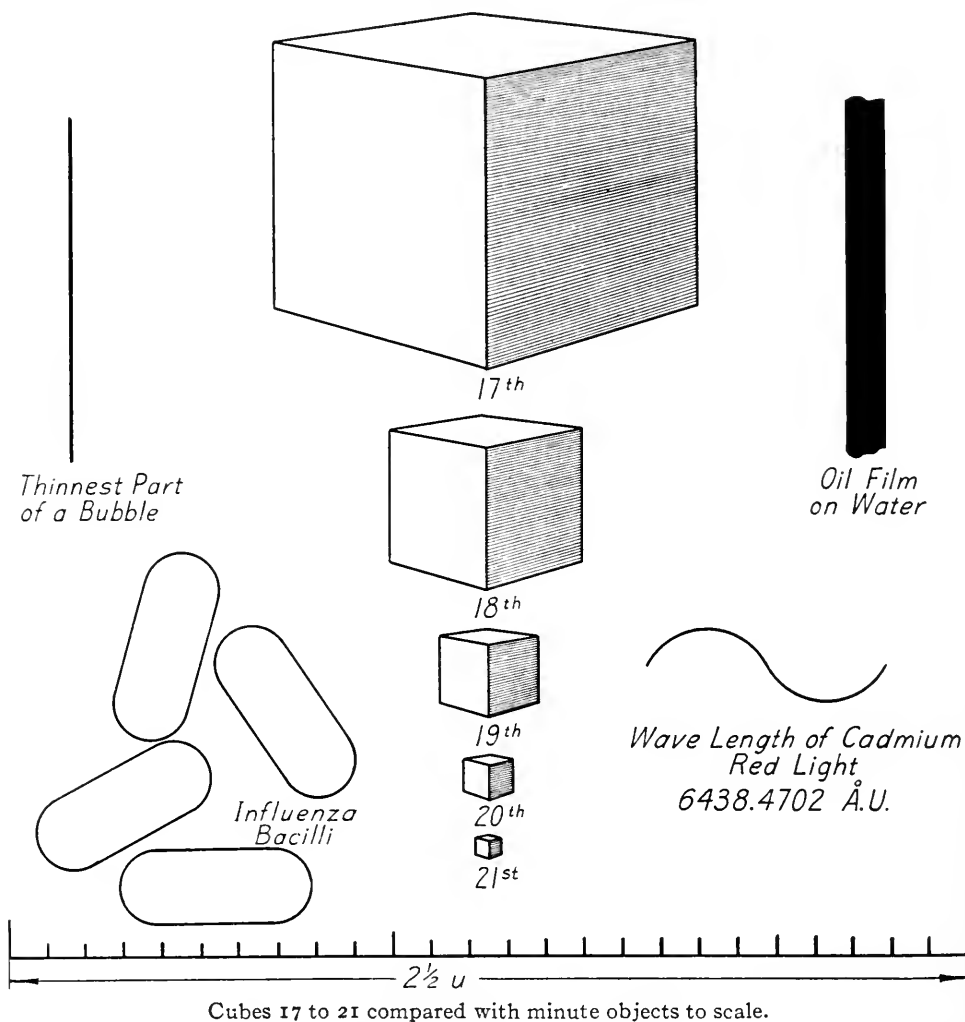
water on the earth is 5×10^{21}, the number of molecules of water in a single tumbler is 10^{25}.

From the above statements it would, at first sight, appear absurd to hope to obtain effects from single atoms, yet this can now be done in several ways, and indeed it is largely due to the results of such experiments that the figures can be stated with so much confidence. Detection of an individual is only feasible in the case of an atom moving with an enormous velocity when, although its mass is so minute, its energy is quite appreciable.

The charged helium atom shot out by radioactive substances in the form of an alpha ray possesses so much energy that the splash of light caused by its impact against a fluorescent screen can be visibly detected, the ionization caused by its passage through a suitable gas can be measured on a sensitive electrometer and, in the beautiful experiments of C. T. R. Wilson, its path in air

FIG. 3.

Caesium

Lead

Carbon
Comparative
Sizes of Atoms

O_2

26th
Arrangement of Lead Atoms

Average Distance
Apart of Molecules in Air

Si

N_2

Atoms in Quartz Crystals $Si O_2$

3·5 uu

Cube 26 showing atoms with scale of reference.
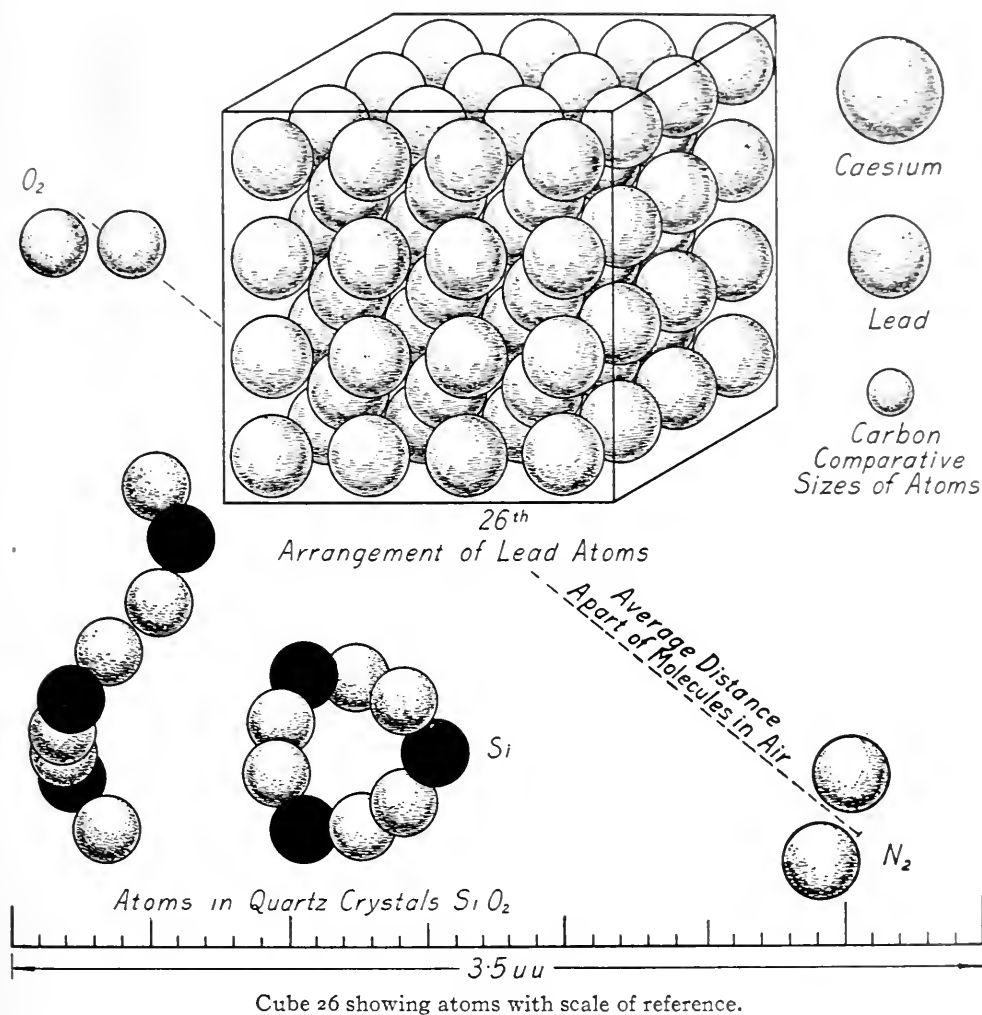
can be both seen and photographed by means of the condensation of water drops upon the atomic wreckage it leaves behind it.

In the first complete Atomic Theory put forward by Dalton in 1803 one of the postulates states that: " Atoms of the same element are similar to one another and equal in weight." Of course, if we take this as a definition of the word " Element " it becomes a truism, but, on the other hand, what Dalton probably meant by an element, and what we understand by the word to-day,

is a substance such as hydrogen, oxygen, chlorine, or lead, which has unique chemical properties and cannot be resolved into more elementary constituents by any known chemical process. For many of the well-known elements Dalton's postulate still appears to be strictly true, but for others, probably the majority, it needs some modification.

The idea that atoms of the same element are all identical in weight could not be challenged by ordinary chemical methods, for the atoms are by definition chemically identical and numerical ratios were only to be obtained in such methods by the use of quantities of the element containing countless myriads of atoms. At the same time it is rather surprising, when we consider the complete absence of positive evidence in its support, that no theoretical doubts were publicly expressed until late in the nineteenth century, first by Schutzenberger and then by Crookes, and that these doubts have been regarded, even up to the last few years, as speculative in the highest degree. In order to dismiss the idea that the atoms of such a familiar element as chlorine might not all be of the same weight, one had only to mention diffusion experiments and the constancy of chemical equivalents. It is only within the last few years that the lamentable weakness of such arguments has been exposed and it has been realized that the experimental separation of atoms differing from each other by as much as 10 per cent. in weight, is really an excessively difficult operation.

There are two ways by which the identity of the weights of the atoms forming an element can be tested. The one is by the direct comparison of the weights of individual atoms, the other is by obtaining samples of the element from different sources or by different processes, which, although perfectly pure, do not give the same chemical atomic weight. It was by the second and less direct of these methods that it was first shown that substances could exist which, though chemically identical, had different atomic weights.

In 1906 Boltwood,[1] at Yale, discovered a new element in the radioactive group which he called ionium, and described as having chemical properties similar to those of thorium. So much was this the case that if, by accident, salts of these two elements were mixed, he found it impossible to separate them again by any of the chemical processes. This chemical identity was confirmed in

the most convincing manner by the later work of Marckwald,
Keetman [2] and Welsbach,[3] although the two elements certainly
had different radioactive properties and it was extremely probable
that they had different atomic weights. More identities of a
similar nature among the radioactive elements were discovered
by Soddy,[4] Hahn,[5] and others,. and the situation in 1910 will
be found admirably summed up by Soddy in his report to the
Chemical Society for that year.[6] In 1912, Russel and Rossi [7]
showed that the spectra of ionium and thorium were indistin-
guishable and Rutherford's theory of the " Nucleus Atom,"
supplied a possible explanation. The association of the chemical
and spectroscopic properties of an element with something more
fundamental than its atomic weight, namely the charge on the
nuclei of its atoms or its " Atomic Number," was proved by the
epoch-making work of Moseley in 1913.[8] This idea gave a
simple and entirely satisfactory meaning to the chemical laws of
the radioactive disintegrations discovered a little earlier and pre-
dicted that among the numerous products of these disintegrations
there must of necessity be some having identical chemical proper-
ties but different atomic weights.

To the latter the name " Isotopes " was applied by Soddy in
the following words: " The same algebraic sum of the positive
and negative charges in the nucleus when the arithmetical sum is
different gives what I call 'isotopes' or 'isotopic elements'
because they occupy the same place in the periodic table. They
are chemically identical, and save only as regards the relatively
few physical properties which depend upon atomic mass directly,
physically identical also."

The theory of isotopes received its most triumphant vindi-
cation, as far as it concerned the products of radioactivity, from
the results of work on the atomic weight of lead. Study of the
radioactive disintegrations shows that the final product of every
series is lead. If we take the main chain of the uranium-radium
transformation this lead must have an atomic weight 206, for it
has lost 5 alpha particles—each of weight 4—since it was radium,
and the atomic weight of radium is 226. On the other hand, if
we take the main thorium chain the lead end product must be
6 alpha particles lighter than thorium (232.15) and so should
have an atomic weight about 208.

Now ordinary lead, from non-radioactive sources has an

atomic weight 207.20, so Soddy[9] suggested in 1913 that the lead derived from minerals containing uranium but no thorium might have a smaller atomic weight than ordinary lead, and on the other hand, the atomic weight of lead from minerals containing thorium but no uranium might be greater.

The first experiments were made by Soddy and Hyman[10] with a very small quantity of lead from Ceylon thorite. This gave a perceptibly higher atomic weight than ordinary lead. Later a large quantity of the same mineral was available. The lead from this when carefully purified gave a density 0.26 per cent. higher than that of common lead. On the assumption that the atomic volumes of isotopes are equal, this figure corresponds to an atomic weight of 207.74. A chemical atomic weight deter-

	Common Lead.	Mixture Australian.	Uranio-Lead.	Percentage Difference.	
	A	B	C	A–B	A–C
Atomic weight	207.19	206.34	206.08	0.42	0.54
Density......................	11.337	11.280	11.273	0.42	0.56
Atomic volume	18.277	18.278	18.281	0.01	0.02
Melting point (absolute)	600.53	600.59	—	0.01	—
Solubility (of nitrate)...........	37.281	37.130	—	0.41	—
Refractive index (nitrate)........	1.7815	1.7814	—	0.01	—
Thermoelectric effect	—	—	—	0.00	—
Spectrum wave-length	—	—	—	0.00	0.00

mination gave 207.694. A sample of the same lead was sent to Vienna where Professor Honigschmid, a well-known expert in such matters, obtained from it a value 207.77 as a mean of eight determinations. These figures not only showed that thorium lead had a higher atomic weight than ordinary lead, but also that their atomic volumes were identical, as expected from theory.[11]

At the same time, as this work was in progress, the leading American authority on atomic weights, T. W. Richards,[12] of Harvard, started a series of investigations on lead derived from various radioactive minerals. The samples of lead from uranium minerals all gave results lower than ordinary lead, as was expected, and one particularly pure specimen of uranio-lead from Norwegian cleveite gave 206.08,[13] a very striking agreement with theory. The following table of properties is taken from his Presidential address to the American Association at Baltimore, December, 1918.

In further confirmation Maurice Curie [14] in Paris reported 206.36 for a lead from carnotite, and a still lower figure, 206.046, was obtained by Honigschmid in Vienna for a lead from the very pure crystallized pitchblende from Morogoro.[15] This is the lowest atomic weight found so far. The highest, 207.9, was also determined by Honigschmid for lead from Norwegian thorite.

In the absence of the special radioactive evidence which can be used in special cases such as that of lead, the presence of isotopes among the inactive elements can only be detected by the direct measurement of the masses of individual atoms. This can be done by the analysis of positive rays.

The condition for the development of these rays is briefly ionization at low pressure in a strong electric field. Ionization, which may be due to collisions or radiation, means in its simplest case the detachment of one electron from a neutral atom. The two resulting fragments carry charges of electricity of equal quantity but of opposite sign. The negatively charged one is the electron, the atomic unit of negative electricity itself, and is the same whatever the atom ionized. It is extremely light and therefore in the strong electric field rapidly attains a high velocity and becomes a cathode ray. The remaining fragment is clearly dependent on the nature of the atom ionized. It is immensely more massive than the electron, for the mass of the lightest atom, that of hydrogen, is about 1850 times that of the electron, and so will attain a much lower velocity under the action of the electric field. However, if the field is strong and the pressure so low that it does not collide with other atoms too frequently, it will ultimately attain a high speed in a direction opposite to that of the detached electron, and become a " positive ray." The simplest form of positive ray is therefore an atom of matter carrying a positive charge and endowed, as a result of falling through a high potential, with sufficient energy to make its presence detectable. Positive rays can be formed from molecules as well as atoms, so that it will at once be seen that any measurement of their mass will give us direct information as to the masses of atoms of elements and molecules of compounds, and that this information will refer to the atoms or molecules *individually*, not, as in chemistry, to the mean of an immense aggregate. It is on this account that the accurate analysis of positive rays is of such importance.

In order to investigate and analyze them it is necessary to obtain intense beams of the rays. This can be done in several ways. The one most generally available is by the use of the discharge in gases at low pressure.

It is somewhat remarkable that notwithstanding the immense amount of research work done on the discharge at low pressure its most obvious phenomena are almost entirely without explanation; modern measurements and other data have merely destroyed the older theories without, as yet, suggesting others to replace them. In discussing positive rays it is of importance to consider the phenomena taking place immediately in front of the cathode of the discharge tube.

The comparatively dimly lit space between the cathode and the bright " negative glow " is named after its discoverer the " Crookes' Dark Space." Its length is roughly inversely proportional to the pressure of the gas in the tube. Its boundary, the edge of the negative glow, is remarkably sharp in most gases, quite amazingly so in pure oxygen. If large plane cathodes are used so that the effect of the glass walls—so far a complete mystery—does not come in, very accurate and consistent measurements of the Crookes' dark space can be made. Working with a very large " guard-ring " cathode, the writer showed in 1907 [16] that its length D could be expressed as

$$D = \frac{A}{P} + \sqrt{\frac{B}{i}}$$

where P is the pressure, i the current density on the surface of the cathode and A and B constants. This expression is fairly exact for ordinary gases, but only approximate for those of the helium group.[17] A varies both with the nature of the gas and the metal used as cathode. With the same metal as cathode it is four to five times as big for hydrogen as for oxygen; using the same gas, it is about twice as big with a silver cathode as for one of aluminum.[18] The value of the remarkable constant B, which is independent of the pressure, is also practically unchanged either by the nature of the gas, or the nature or even the shape of the cathode.

During these investigations it was also demonstrated that in the absence of the positive column, the whole of the potential

V required to maintain the discharge, takes place between the cathode and the negative glow, and its relation to the current may be expressed by the equation

$$V = E + \frac{F\sqrt{i}}{P}$$

E and F being constants which depend on the nature of the gas and the metal used as cathode.

Measurements of the distribution of potential in the dark space by a method which appears free from objection [19] show that the field is practically zero in the negative glow itself and increases in a linear manner as we move towards the cathode. This means that the density of the positive electrification (excess of positive over negative ions) in the dark space is constant.

No theory yet put forward can account for these numerical relations; one can, however, be certain that ionization is going on at all points throughout the dark space, and that it reaches a very high intensity in the negative glow.[20] This ionization is probably caused for the most part by electrons liberated from the surface of the cathode (cathode rays). These, when they reach a speed sufficient to ionize by collision, liberate more free electrons which, in their turn, become ionizing agents, so that the intensity of ionization from this cause will tend to increase as we move away from the cathode.

The liberation of the original electrons from the surface of the cathode is generally regarded as due to the impact of the positive ions (positive rays) generated in the negative glow and the dark space. Even this idea, for which there is a fair amount of definite evidence, is now called in question for Ratner [21] has recently described experiments proving " that the initial discharge of electricity through vacuum tubes is not brought about by the impact of positive ions against the surface of the cathode, and that positive ions impinging upon the cathode with velocities corresponding to a fall through a potential difference up to 2000 volts, are unable to liberate electrons from the surface of the cathode."   It must, however, be borne in mind that the nature of the positive ions used in Ratner's experiments is not known with certainty, and that the intensity of bombardment was of an entirely different and smaller order than that usually associated with normal discharge.

During the work on the length of the dark space a very curious and interesting phenomenon was observed in hydrogen and all the gases of the helium group. This consisted of a dark space very small and very dark, immediately in front of the cathode, inside the Crookes' dark space.[22] It can only be clearly seen by looking across the face of a large plane cathode when its appearance in pure helium or neon is very striking. Its properties are completely different to those of the Crookes' dark space. Its length, which is usually less than a millimetre, is independent of the pressure and varies roughly inversely as the square root of the current density. As the field close to the cathode varies directly as the square root of the current density this suggested at once that the new dark space represented a definite constant fall of potential. There is now little doubt that this " Primary Dark Space," as it has been called, defines the distance through which an electron, starting from rest at the surface of the cathode, must fall before it acquires sufficient energy to ionize the gas by collision. This explanation is supported in a striking manner by the appearance of the phenomenon when the current density is greatly reduced. Under these conditions alternate dark and bright bands, equally spaced, appear in front of the cathode exactly as would be expected from the production of successive generations of ions. Further support is given by the measurements in hydrogen and helium which indicate that the actual fall of potential across the primary dark space is twice as great for helium as for hydrogen and, on certain assumptions, is approximately equal to the ionization potential of these gases determined by other means.

In addition to cathode ray ionization the positive rays travelling towards the cathode themselves are capable of ionizing the gas, and radiation may also play an important part in the same process. The surface of the cathode will therefore be under a continuous hail of positively charged particles. Their masses may be expected to vary from that of the lightest atom to that of the heaviest molecule capable of existence in the discharge tube, and their energies from an indefinitely small value to a maximum expressed by the product of the charge they carry × the total potential applied to the electrodes. The latter is practically the same as the fall of potential across the dark space. If the cathode be pierced the rays pass through the aperture and form

a stream heterogeneous both in mass and velocity which can be subjected to examination and analysis.

In Sir J. J. Thomson's [23] " parabola " method of analysis of positive rays the particles after reaching the surface of the cathode enter a long and very fine metal tube. By this means a narrow beam of rays is produced which is subjected to deflection by electric and magnetic fields and finally falls upon a screen of fluorescent material or a photographic plate. The fields are arranged so that the two deflections are at right angles to each other. If we call the displacement on the plate due to the electric field x and that due to the magnetic field y for any particle (x, y) will be the rectangular coördinates of the point where it strikes the plate. Simple dynamics show that if the angle of deflection is small, for a particle of mass m, charge e and velocity v, the electric deflection $x = k(Xe/mv^2)$ and the magnetic deflection $y = k'(He/mv)$ where X and H are the magnetic and electric fields and k and k' constants depending solely on the dimensions and form of the apparatus. Hence if both fields are on together the locus of impact of all particles of the same $\frac{e}{m}$ but varying velocity will be a parabola. Since e must be the electronic charge, or a simple multiple of it, measurement of the relative positions of the parabolas on the plate enables us to calculate the relative masses of the particles producing them, that is, the masses of the individual atoms. The fact that the streaks were definite, sharp parabolas, and not mere blurs, constituted the first direct proof that atoms of the same element were, even approximately, of equal mass.

Many gases were examined by this method and some remarkable compounds, such as H_3, discovered by its means. When in 1912 neon was introduced into the discharge tube, it was observed to exhibit an interesting peculiarity. This was that whereas all elements previously examined gave single, or apparently single, parabolas, that given by neon was definitely double. The brighter curve corresponded roughly to an atomic weight of 20, the fainter companion to one of 22, the atomic weight of neon being 20.20. In consequence of reasoning adduced from the characteristics of the line 22, Sir J. J. Thomson was of the opinion that it could not be attributed to any compound, and that therefore it represented a hitherto unknown elementary constituent of neon.

This agreed very well with the idea of isotopes which had just been promulgated, so that it was of great importance to investigate the point as fully as possible.

The first line of attack was an attempt at separation by fractional distillation over charcoal cooled with liquid air, but even after many thousands of operations the result was entirely negative. The density of the fractions was determined by means of a special quartz microbalance [24] and was found to agree in every case with the accepted atomic weight of 20.20 [25] to an accuracy of 1 in 1000.

The second method employed was that of fractional diffusion through pipeclay, which after months of arduous work gave a small but definite positive indication of separation. A difference of about 0.7 per cent.[26] between the densities of the heaviest and lightest fractions was obtained. If V is the initial and v the residual volume of gas, Rayleigh's [27] theory of diffusion gives an enrichment of approximately $(V/v)^{1/21}$ in respect to the heavier constituent in the residue in the case of neon. This is the result of a single operation and the effective ratio V/v can be increased indefinitely by repeated operations, in these experiments it amounted to several thousand, but from the nature of the work cannot be stated exactly. If, to be perfectly safe, we take V/v as between 500 and 10,000, the theoretical increase in density of the heaviest fraction over normal should lie between 0.34 and 0.55 per cent. It was actually 0.4, quite a reasonable figure considering the inefficiency of the method. The decrease in density in the lightest fraction was rather less owing to the loss of a portion of the gas during the experiment. When the war interrupted the research, it might be said that several independent lines of reasoning pointed to the conclusion that neon was a mixture of isotopes, but none of these could be said to carry absolute conviction.

By the time the work was resumed in 1919 the existence of isotopes among the products of radioactivity had been put beyond all reasonable doubt by the work on the atomic weight of lead and was accepted generally. This fact automatically increased both the value of the evidence of the complex nature of neon and the urgency of its definite confirmation. It was realized that separation could only be very partial at the best and that the most satisfactory proof would be afforded by measurements of atomic weight by the method of positive rays. These would have to be

so accurate as to prove beyond dispute that the accepted atomic weight lay between the real atomic weights of the constituents, but corresponded with neither of them.

The parabola method of analysis was not sufficient for this, but the required accuracy was achieved by the arrangement illustrated diagrammatically in Fig. 4.[28] The exact mathematical analysis has now been worked out by R. H. Fowler,[29] but it is proposed to give only the approximate theory here for the sake of simplicity.

The rays after arriving at the cathode face pass through two very narrow parallel slits of special construction S_1 S_2, and the resulting thin ribbon is spread out into an electric spectrum by means of the parallel plates P_1, P_2. After emerging from the electric field the rays may be taken, to a first order of approximation, as radiating from a virtual source Z half-way through the field on the line S_1 S_2. A group of these rays is now selected by means of the diaphragm D, and allowed to pass between the parallel poles of a magnet. For simplicity the poles are taken as circular, the field between them uniform and of such sign as to bend the rays in the opposite direction to the foregoing electric field.

If θ and φ be the angles (taken algebraically) through which the selected beam of rays is bent by passing through fields of strength X and H, then

$$\theta v^2 = lX\frac{e}{m}\,(1), \text{ and } \varphi v = LH\frac{e}{m}\,(2),$$

where l, L are the lengths of the paths of the rays in the fields. Equation (1) is only true for small angles, but exact enough for practice. It follows that over the small range of θ selected by the diaphragm θv^2 and φv are constant for all rays of given e/m, therefore

$$\frac{\delta\theta}{\theta}+\frac{2\delta v}{v}=0, \text{ and } \frac{\delta\varphi}{\varphi}+\frac{\delta v}{v}=0,$$

so that

$$\frac{\delta\theta}{\theta}=\frac{2\delta\varphi}{\varphi},$$

when the velocity varies in a group of rays of given e/m. This equation appears correct within practical limits for large circular pole-pieces.

Referred to axes OX, OY the focus is at $r \cos (\varphi - 2\theta')$, $r \sin (\varphi - 2\theta')$, or r, $b.2\theta'$; so that to a first-order approximation, whatever the fields, so long as the position of the diaphragm is fixed, the foci will all lie on the straight line ZF drawn through Z parallel to OX. For purposes of construction G the image of Z in OY is a convenient reference point, φ being here equal to $4\theta'$. It is clear that a photographic plate, indicated by the thick line, will be in fair focus for values of e/m over a range large enough for accurate comparison of masses.

Since it is a close analogue of the ordinary spectrograph and gives a " spectrum " depending upon mass alone, the instrument

FIG. 4.
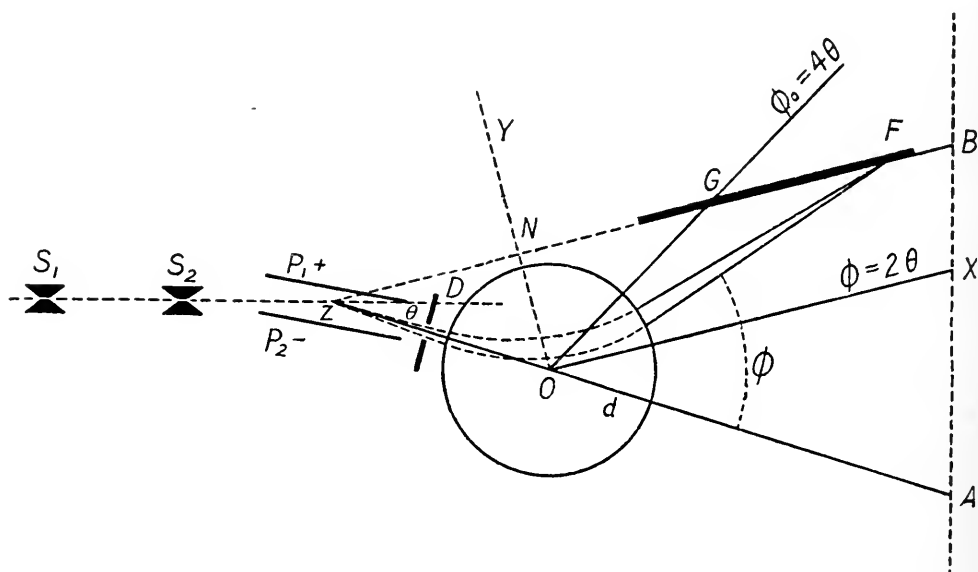
Diagram of mass-spectrograph.

is called a " mass-spectrograph " and the spectrum it produces a " mass-spectrum."

Fig. 5 shows a number of typical mass-spectra obtained by this means. The numbers above the lines indicate the masses they correspond to on the scale $O = 16$. It will be noticed that the displacement to the right with increasing mass is roughly linear. The measurements of mass made are not absolute, but relative to lines which correspond to known masses. Such lines due to hydrogen, carbon, oxygen and their compounds are generally present as impurities or purposely added, for pure gases are not suitable for the smooth working of the discharge tube. The two principal groups of these reference lines are the C_1 group due to

FIG. 5.

Typical mass-spectra.

C (12), CH (13), CH_2 (14), CH_3 (15), CH_4 or O (16), and the C_2 group (24 to 30) containing the very strong line C_2H_4 or CO (28). These groups will be seen in several of the spectra

reproduced, and they give, with the CO_2 line (44), a very good scale of reference.

It must be remembered that the ratio of mass to charge is the real quantity measured by the position of the lines. Many of the particles are capable of carrying more than one charge. A particle carrying two charges will appear as having half its real mass, one carrying three charges as if its mass was one-third, and so on. Lines due to these are called lines of the second and third order. Lines of high order are particularly valuable in extending our scale of reference.

When neon was introduced into the apparatus four new lines made their appearance at 10, 11, 20 and 22. The first pair are second order lines and are fainter than the other two. All four are well placed for direct comparison with the standard lines, and a series of consistent measurements showed that to within about one part in a thousand the atomic weights of the isotopes composing neon are 20 and 22 respectively. Ten per cent. of the latter would bring the mean atomic weight to the accepted value of 20.20, and the relative intensity of the lines agrees well with this proportion. The isotopic constitution of neon seems therefore settled beyond all doubt.

The element chlorine was naturally the next to be analyzed, and the explanation of its fractional atomic weight was obvious from the first plate taken. Its mass spectrum is characterized by four strong first order lines at 35, 36, 37, 38, with fainter ones at 39, 40. There is no sign whatever of any line at 35.46. The simplest explanation of the group is to suppose that the lines 35 and 37 are due to the isotopic chlorines and lines 36 and 38 to their corresponding hydrochloric acids. The elementary nature of lines 35 and 37 is also indicated by the second order lines at 17.5, 18.5, and also, when phosgene was used, by the appearance of lines at 63, 65, due to $COCl^{35}$ and $COCl^{37}$.

Quite recently it has been found possible to obtain the spectrum of negatively charged rays. These rays are formed by a normal positively charged ray picking up two electrons. On the negative spectrum of chlorine only two lines, 35 and 37, can be seen, so that the lines at 36 and 38 cannot be due to isotopes of the element. These results, taken with many others which cannot be stated here in detail, show that chlorine is a complex element, and that its principal isotopes are of atomic weight 35 and 37. There may be,

in addition, a small proportion of a third of weight 39, but this is doubtful. Spectra II, III and IV show the results with chlorine taken with different magnetic field strengths.

The mass spectrum of argon shows an exceedingly bright line at 40, with second order line at 29, and third order line at $13^1/_3$. The last is particularly well placed between known reference lines, and its measurement showed that the triply-charged atom causing it had a mass 40 very exactly. Now the accepted atomic weight of argon is less than 40, so the presence of a lighter isotope was suggested. This was found at 36, and has now been fully substantiated; its presence to the extent of about 3 per cent. is sufficient to account for the mean atomic weight obtained by density determinations.

The elements hydrogen and helium present peculiar difficulties since their lines are so far removed from the ordinary reference scale, but, as the lines were expected to approximate to the terms of the geometrical progression 1, 2, 4, 8, etc., the higher terms of which are known, a special method was adopted by which a two to one relation could be tested with some exactness. Two sets of accumulators were selected, each giving very nearly the same potential of about 250 volts. The potentials were then made exactly equal by means of a subsidiary cell and a current-divider, the equality being tested to well within 1000 by means of a null instrument. If exposures are made with such potentials applied to the electric plates first in parallel and then in series, the magnetic field being kept constant, all masses having an exact two to one relation will be brought into coincidence on the plate. Such coincidences cannot be detected on the same spectrum photographically; but if we first add and then subtract a small potential from one of the large potentials, two lines will be obtained which closely bracket the third. To take an actual instance—using a gas containing hydrogen and helium, with a constant current in the magnet of 0.2 ampere, three exposures were made with electric fields of 250, 500 + 12, and 500 − 12 volts, respectively. The hydrogen molecule line was found symmetrically bracketed by a pair of atomic lines (Spectrum VII, a and c), showing within experimental error that the mass of the molecule is exactly double the mass of the atom. When after a suitable increase of the magnetic field the same procedure was applied to the helium line and that of the hydrogen molecule, the bracket was no longer

symmetrical (Spectrum VII, b), nor was it when the hydrogen molecule was bracketed by two helium lines (d). Both results show in an unmistakable manner that the mass of He is less than twice that of H_2. In the same way He was compared with O^{++} and H_3. The values obtained by its use can be checked in the ordinary way by comparing He with C^{++} and H_3 with He, these pairs being close enough together for the purpose. The following table gives the range of values obtained from the most reliable plates:

Line.	Method.	Mass assumed.	Mass deduced.
He . . .	Bracket	$O^{++} = 8$	3.994–3.996
	Direct	$C^{++} = 6$	4.005–4.010
H₃ . . .	Bracket	$C^{++} = 6$	3.025–3.027
	Direct	He $= 4$	3.021–3.030
H₂ . . .	Bracket	He $= 4$	2.012–2.018

From these figures it is safe to conclude that hydrogen is a simple element and that its atomic weight, determined with such consistency and accuracy by chemical methods, is the true mass of its atom.[30]

The heavy inert gases give interesting and complicated results. Krypton is characterized by a remarkable group of five strong lines at 80, 82, 83, 84, 86, and a faint sixth at 78. This cluster of isotopes is beautifully reproduced with the same relative values of intensity in the second, and fainter still in the third order. These multiply-charged clusters give most reliable values of mass, as the second order can be compared with A (40) and the third with CO or N_2 (28) with the highest accuracy. It will be noted that one member of each group is obliterated by the reference line, but not the same one. The singly and doubly charged krypton clusters can be seen to the right and left of Spectrum VIII. It will be noticed that krypton is the first element examined which shows unmistakable isotopes differing by one unit only.

Xenon gives five strong lines 129, 131, 132, 134, 136 and some indication of two faint and doubtful ones 128 and 130.

Mercury probably consists of six isotopes. Its first, second, third, and higher order lines appear as a series of characteristic groups around positions corresponding to masses 200, 100,

$66^2/_3$, etc. Some of these will be easily distinguished on the spectra reproduced.

In addition to those mentioned above the elements boron, fluorine, silicon, bromine, sulphur, phosphorus, iodine and nickel have been analyzed by the mass-spectrograph, using the discharge tube method for producing their positive rays. Selenium, tellurium, antimony and tin have been attacked but not yet successfully.

Positive rays of the metallic elements cannot, in general, be obtained by the discharge tube method, but require special devices for their production. Thus the isotopic nature of lithium was first demonstrated by the use of anode rays derived from anodes containing salts of that metal.[31] Later by applying the mass-spectrograph to them all the other alkali metals were successfully analyzed.[32] Sodium and cæsium appear to be simple elements whilst lithium, potassium and rubidium each consist of two isotopes.

A powerful and ingenious method of generating positive rays of metallic elements has been worked out and used with great success by Dempster at Chicago.[33] He employs the element in the metallic state and ionizes its vapor by means of a subsidiary beam of cathode rays. The ions so produced are allowed to fall through a definite potential and being therefore of constant energy can be analyzed by the use of a magnetic field alone. By this arrangement Dempster discovered the three isotopes of magnesium [34] and confirmed those of lithium. A full account of this work has lately appeared.[35] Still more recently he has obtained results with calcium and zinc which indicate that the former consists almost entirely of an isotope 40 with probable traces of another 44, and that the latter has four isotopes—64, 66, 68 and 70. Since the vast majority of the elements not yet analyzed are metals Dempster's method is likely to yield enormously important results in the future. A complete list of the isotopes of the non-radioactive elements so far discovered is given on the following page.

By far the most important general result of these investigations is that, with the exception of hydrogen, the weights of the atoms of all the elements measured, and therefore almost certainly of all elements are whole numbers to the accuracy of

experiment. In the majority of the figures obtained by means of the mass-spectrograph this accuracy is one part in a thousand. Of course the error expressed in fractions of a unit increases

Table of Elements and Isotopes.

Element.	Atomic number.	Atomic weight.	Minimum number of isotopes.	Masses of isotopes in order of intensity.
H	1	1.008	1	1.008
He	2	4.00	1	4
Li	3	6.94	2	7, 6
Be	4	9.1	1	9
B	5	10.9	2	11, 10
C	6	12.00	1	12
N	7	14.01	1	14
O	8	16.00	1	16
F	9	19.00	1	19
Ne	10	20.20	2	20, 22, (21)
Na	11	23.00	1	23
Mg	12	24.32	3	24, 25, 26
Si	14	28.3	2	28, 29, (30)
P	15	31.04	1	31
S	16	32.06	1	32
Cl	17	35.46	2	35, 37, (39)
A	18	39.88	2	40, 36
K	19	39.10	2	39, 41
Ni	28	58.68	2	58, 60
As	33	74.96	1	75
Br	35	79.92	2	79, 81
Kr	36	82.92	6	84, 86, 82, 83, 80, 78
Rb	37	85.45	2	85, 87
I	53	126.92	1	127
X	54	130.2	5, (7)	129, 132, 131, 134 136, (128, 130?)
Cs	55	132.81	1	133
Hg	80	200.6	(6)	(197-200), 202 204

Dempster's latest results.

Ca	20	40.07	(2)	40 (44)
Zn	30	65.37	(4)	(64, 66, 68, 70)

with the weight measured, but with the lighter elements the divergence from the whole number rule is extremely small.

This enables the most sweeping simplifications to be made in our ideas of mass. The original hypothesis of Prout, put forward in 1815, that all atoms were themselves built of atoms of protyle, a hypothetical element which he tried to identify with

hydrogen, is now reëstablished, with the modification that the primordial atoms are of two kinds: Protons and electrons, the atoms of positive and negative electricity.

The Rutherford atom, whether we take Bohr's or Langmuir's development of it, consists essentially of a positively charged central nucleus around which are set planetary electrons at distances great compared with the dimensions of the nucleus itself.

As has been stated, the chemical properties of an element depend solely on its atomic number, which is the charge on its nucleus expressed in terms of the unit charge, e. A neutral atom of an element of atomic number N has a nucleus consisting of $K + N$ protons and K electrons, and around this nucleus are set N electrons. The weight of an electron on the scale we are using is 0.0005, so that it may be neglected. The weight of this atom will therefore be $K + N$, so that if no restrictions are placed on the value of K any number of isotopes are possible.

A statistical study of the results given above shows that the natural restrictions can be stated in the form of rules as follows:

In the Nucleus of an Atom There is Never Less Than One Electron to Every Two Protons.—There is no known exception to this law. It is the expression of the fact that if an element has an atomic number N the atomic weight of its lightest isotope cannot be less than $2N$. Worded as above, the ambiguity in the case of hydrogen is avoided. True atomic weights corresponding exactly to $2N$ are known in the majority of the lighter elements up to A.[36] Among the heavier elements the difference between the weight of the lightest isotope and the value $2N$ tends to increase with the atomic weight; in the cases of mercury it amounts to 37 units. The corresponding divergence of the *mean* atomic weights from the value $2N$ has of course been noticed from the beginning of the idea of atomic number.

The Number of Isotopes of an Element and their Range of Atomic Weight Appear to Have Definite Limits.—Since the atomic number only depends on the *net* positive charge in the nucleus there is no arithmetical reason why an element should not have any number of isotopes. So far the largest number determined with certainty is 6 in the case of krypton. It is possible that xenon has even more, but the majority of complex elements have only two each. The maximum difference between the lightest

and heaviest isotope of the same element so far determined is 8 units in the cases of krypton and xenon. The greatest proportional difference, calculated on the lighter weight, is recorded in the case of lithium, where it amounts to one-sixth. It is about one-tenth in the case of boron, neon, argon and krypton.

The Number of Electrons in the Nucleus Tends to be Even.— This rule expresses the fact that in the majority of cases even atomic number is associated with even atomic weight and odd with odd. If we consider the three groups of elements, the halogens, the inert gases and the alkali metals, this tendency is very strongly marked. Of the halogens—odd atomic numbers—all 6 (+1?) atomic weights are odd. Of the inert gases—even atomic numbers 13 (+2?) are even and 3 odd. Of the alkali metals—odd atomic numbers—7 are odd and 1 even. In the few known cases of elements of other groups the preponderance, though not so large, is still very marked and nitrogen is the only element yet discovered to consist entirely of atoms whose nuclei contain an odd number of electrons.

If we take the natural numbers 1 to 40, we find that those not represented by known atomic weights are 2, 3, 5, 8, 13, (17), (18), 21, (33), 34, (38). It is rather remarkable that these gaps, with the exception of the four in parenthesis, are represented by a simple mathematical series of which any term is the sum of the two previous terms.

In consequence of the whole number rule there is now no logical difficulty in regarding protons and electrons as the bricks out of which atoms have been constructed. An atom of atomic weight m is turned into one of atomic weight $m + 1$ by the addition of a proton plus an electron. If both enter the nucleus, the new element will be an isotope of the old one, for the nuclear charge has not been altered. On the other hand, if the proton alone enters the nucleus and the electron remains outside, an element of next higher atomic number will be formed. If both these new configurations are possible, they will represent elements of the same atomic weight but with different chemical properties. Such elements are called " isobares " and are actually known.

The case of the element hydrogen is unique; its atom appears to consist of a single proton as nucleus with one planetary electron. It is the only atom in which the nucleus is not composed of a number of protons packed exceedingly closely together.

Theory indicates that when such close packing takes place the effective mass will be reduced, so that when four protons are packed together with two electrons to form the helium nucleus this will have a weight rather less than four times that of the hydrogen nucleus, which is actually the case. It has long been known that the chemical atomic weight of hydrogen was greater than one-quarter of that of helium, but so long as fractional weights were general there was no particular need to explain this fact, nor could any definite conclusions be drawn from it. The results obtained by means of the mass-spectrograph remove all doubt on this point, and no matter whether the explanation is to be ascribed to packing or not, we may consider it absolutely certain that if hydrogen is transformed into helium a certain quantity of mass must be annihilated in the process. The cosmical importance of this conclusion is profound and the possibilities it opens for the future very remarkable, greater in fact than any suggested before by science in the whole history of the human race.

We know from Einstein's Theory of Relativity that mass and energy are interchangeable [36] and that in C.G.S. units a mass m at rest may be expressed as a quantity of energy mc^2, where c is the velocity of light. Even in the case of the smallest mass this energy is enormous. The loss of mass when a single helium nucleus is formed from free protons and electrons amounts in energy to that acquired by a charge e falling through a potential of nearly thirty million volts. If instead of considering single atoms we deal with quantities of matter in ordinary experience the figures for the energy become prodigious.

Take the case of one gramme atom of hydrogen, that is to say the quantity of hydrogen in 9 c.c. of water. If this is entirely transformed into helium the energy liberated will be

$$.0077 \times 9 \times 10^{20} = 6.93 \times 10^{18} \text{ ergs.}$$

Expressed in terms of heat this is 1.66×10^{11} calories or in terms of work 200,000 kilowatt hours. We have here at last a source of energy sufficient to account for the heat of the sun.[37] In this connection Eddington remarks that if only 10 per cent. of the total hydrogen on the sun were transformed into helium enough energy would be liberated to maintain its present radiation for a thousand million years.

Should the research worker of the future discover some means of releasing this energy in a form which could be employed, the human race will have at its command powers beyond the dreams of scientific fiction; but the remote possibility must always be considered that the energy once liberated will be completely uncontrollable and by its intense violence detonate all neighboring substances. In this event the whole of the hydrogen on the earth might be transformed at once and the success of the experiment published at large to the universe as a new star.

In considering the spectra of isotopes there is every reason to suppose that the light emitted by an atom will depend upon the movements of its planetary electrons, and therefore upon the force controlling these, that is, the nuclear charge. We therefore expect that the difference between the spectra of two isotopes will be extremely small since the nuclear charges are identical. This expectation is borne out in practice and the difference in wave-length has only been detected in the case of the isotopes of lead. Aronberg,[38] in 1917, discovered a shift of 0.0044 A between ordinary lead and a radio lead of atomic weight 206.3. This result has been confirmed the subsequent work of Merton,[39] who has recently measured a shift of 0.011 A in one of the lines of an extremely pure Carnotite lead as compared with the same line in ordinary lead. These shifts, though extremely minute, are however hundreds of times larger than the ones predicted by the simple application of the Bohr theory.

The artificial separation of the isotopes of non-radioactive elements in an exceedingly difficult operation; indeed, had it been otherwise they must have been discovered long ago. In the case of neon already described, which is a particularly favorable one, the extreme difference between the lightest and heaviest fractions amounted to 0.13 of a unit of atomic weight. Harkins,[40] using a somewhat similar diffusion method, has successfully separated the isotopic hydrochloric acids and obtained a shift of 0.055 of a unit. A beautiful method applicable to certain liquids has been developed by Bronsted and Hevesy.[41] This consists in allowing the liquid to evaporate at so low a temperature and pressure that none of the molecules escaping from its surface can ever return to it again, a concentration of the heavier constituent in the residue must then result. They first applied it to mercury and the latest separation achieved with the isotopes

of that element is indicated by the figure 0.99974 and 1.00023 for the densities of the lightest and heaviest fraction respectively, the normal density being taken as unity. In atomic weight this separation corresponds to a shift of 0.1 of a unit. They have also applied the same method to a solution of hydrochloric acid in water and obtained a change of atomic weight of about 0.02 of a unit.[42]

Several other methods of partial separation have been suggested but the only ones which have been successful in practice are those mentioned above. Complete separation can be achieved by means of positive ray analysis, but the quantities to be obtained in this way are too minute to be of the slightest practical importance. The fact that many of the most familiar elements prove to be mixtures of isotopes is of fundamental theoretical importance, but when we consider the extreme difficulties of their separation it seems very unlikely, unless some entirely new method is discovered, that the numerical constants of chemistry are likely to be affected seriously for some time to come.

[1] Boltwood: *Amer. J. Sci.*, **22**, 537, 1906; **24**, 370, 1907.
[2] Keetman: *Jahr. Radioactivität*, **6**, 269, 1909.
[3] A. von Welsbach: *Wien. Ber.*, iia, **119**, 1011, 1910.
[4] Soddy: *Trans. Chem. Soc.*, **99**, 72, 1911.
[5] Hahn and Meitner: *Physikal. Zeitsch.*, **11**, 493, 1910.
[6] *Chem. Soc. Ann. Rep.*, 285, 1910.
[7] Russel and Rossi: *Proc. Roy. Soc.*, **77A**, 478, 1912.
[8] Moseley: *Phil. Mag.*, **26**, 1031, 1913.
[9] *Ann. Rep. Chem. Soc.*, 269, 1913.
[10] Soddy and Hyman: *Trans. Chem. Soc.*, **105**, 1402, 1914.
[11] Soddy: *Roy. Ins.*, May 18, 1917.
[12] Richards and Lembert: *J. Amer. Chem. Soc.*, **36**, 1329, 1914.
[13] Richards and Wadsworth: *J. Amer. Chem. Soc.*, **38**, 2613, 1916.
[14] M. Curie: *Compt. Rend.*, **158**, 1676, 1914.
[15] Honigschmid: *Zeit. Elektrochem.*, **24**, 163, 1918; **25**, 91, 1919.
[16] Aston: *Proc. Roy. Soc.*, **79A**, 80, 1907.
[17] Aston and Watson: *Ibid.*, **86A**, 168, 1912.
[18] Aston: *Ibid.*, **87A**, 428, 437, 1912.
[19] Aston: *Proc. Roy. Soc.*, **84A**, 526, 1911.
[20] Aston: *Proc. Roy. Soc.*, **96A**, 200, 1919.
[21] Ratner: *Phil. Mag.*, **40**, 795, 1920.
[22] Aston: *Proc. Roy. Soc.*, **80A**, 45, 1907.
[23] J. J. Thomson: *Rays of Positive Electricity*.
[24] Aston: *Proc. Roy. Soc.*, **86A**, 1912.
[25] Watson: *J. C. S. Trans.*, **1**, 810, 1910.
[26] Aston: Brit. Asso., 1913.

[27] Rayleigh: *Phil. Mag.*, **42**, 493, 1896.

[28] Aston: *Phil. Mag.*, **38**, 707, 1919; *Phil. Mag.*, **39**, 612, May, 1920.

[29] Aston and Fowler: *Phil. Mag.*, 1922.

[30] Aston: *Phil. Mag.*, **39**, 621, 1920.

[31] Aston and Thomson: *Nature*, Feb. 24, 1921.

[32] Aston: *Phil. Mag.*, **42**, 436, 1921.

[33] Dempster: *Science*, Dec. 10, 1920.

[34] Dempster: *Science*, April 15, 1921.

[35] Dempster: *Phys. Rev.*, **18**, 415, 1921.

[36] Eddington: " Time, Space and Gravitation," p. 146, Cambridge, 1920.

[37] Eddington: Brit. Assoc. address, 1920; Perrin: *Scientia*, Nov., 1921.

[38] Aronberg: *Proc. Nat. Acad. Sci.*, **3**, 710, 1917, and *Astrophys. Jour.*, **47**, 96, 1918.

[39] Merton: *Proc. Roy. Soc.*, **99A**, 87, 1921.

[40] Harkins and Hayes: *J. Amer. Chem. Soc.*, **43**, 1803, 1921.

[41] Bronsted and Hevesy: *Phil. Mag.*, **43**, 31, 1922.

The Probability of Spontaneous Crystallization of Supercooled Liquids.

C. N. Hinshelwood and H. Hartley. (*Phil. Mag.*, January, 1922.)—A hundred tubes containing solutions of the organic substances employed—salol, phenol, etc.—were given the same heat treatment, then placed in a thermostat and the number of tubes in which crystallization had occurred was observed at intervals. These investigators found that their results confirmed the conclusions of their predecessors "that the tendency of a supercooled liquid to crystallize depends upon the temperature to which it has been previously heated, on the number of times fusion and solidification have taken place, and on the length of time it has been maintained in the fused state." The tendency of salol to crystallize was found to be controlled by the highest temperature to which it had been heated without regard to whether crystallization had or had not taken place before the experiments were counted.

Some tubes lost progressively the tendency to crystallize. When they were exposed afresh to the air for a time and then resealed they were found to have regained the power.

These conclusions are drawn:

" 1. In the case of these substances crystallization is provoked by the colloidal organic dust particles from the air.

" 2. The activity of these particles diminishes in general as the result of heating or aging.

" 3. Their effectiveness depends upon their radius. If this is equal to the radius of a small particle of the solid which should thermodynamically be in equilibrium with the supercooled liquid, then crystallization occurs at once. If the radius is less than this, the supercooled liquid has an average life depending on the discrepancy between the equilibrium radius and the radius of the particles present."   G. F. S.

APLANATIC (OR CARTESIAN) OPTICAL SURFACES.*

BY

JAMES P. C. SOUTHALL, A.M.

Professor of Physics, Department of Physics, Columbia University, New York.
Member of the Institute.

HISTORICAL AND INTRODUCTORY.

LONG ago in his celebrated treatise on Geometry, Descartes described the focal properties of the curves which have been known ever since as the famous Ovals of Descartes, and whose equation is usually given in the form

$$r \pm \mu\, r' = a \; ;$$

where r, r' denote the distances of a point on the curve from two fixed foci and μ and a are constants. In his *Dioptrique* Descartes explained, as Huygens tells us, " the use of these lines in relation to refraction." Geometers have found much enjoyment in the study of these curves. In Williamson's " Differential Calculus," which used to be a famous text-book in England and in this country, an entire chapter is devoted to the subject of the " Cartesian Oval," and the curious reader will find there a very original and interesting discussion of its properties. The surface which is generated by the revolution of this curve around the straight line joining the foci as axis may be called here the Cartesian Surface. Theoretically, at least, a certain physical importance may be attached to this surface, because it represents the precise geometrical form which an optical surface should have in order to transmit radiant energy, either by refraction or by reflection, according to the known laws of these phenomena, accurately from one focus to the other. Accordingly, at least some allusion to this surface is made in nearly all the text-books and treatises on geometrical optics; although usually the subject is dismissed as having little practical significance, with perhaps an exception in favor of the parabolic reflector which is a special form of the surface for a mirror when one of the foci is infinitely far away. One of the earliest mathematical treatments of these optical surfaces in English is to be found in Sir John Herschel's article on " Light " in the *Encyclopædia metropolitana;* and

---

* Communicated by the Author.

there are also two admirable chapters on the subject in Lloyd's
" Treatise on Light and Vision " (London, 1831). In the
appendix to the American edition of Brewster's " Optics " (Phila-
delphia, 1835), Professor Bache, the accomplished editor of this
volume, has likewise devoted several pages to a discussion of the
optical properties of these surfaces. But in more modern works,
as, for example, Heath's " Geometrical Optics," not much space
is given to this subject. Among German writers reference may be
made to the treatises of Czapski, Lummer, Drude and von Rohr,
in each of which there may be found a more or less extensive
treatment of the so-called Cartesian surface.

The earlier writers on optics, for example, Coddington,
Herschel, etc., spoke of an optical system as being " aplanatic,"
meaning thereby that it was so contrived that rays proceeding
from a certain point on the optical axis issued from the system
so as to be again reunited at a corresponding point on the axis.
Modern writers, following Abbe, have restricted the meaning of
this term so as to include also the fulfilment of the so-called
" sine-condition " as an additional requisite of " aplanatism."
But if the term is employed in its original wider sense (as will
be done in this paper), the Cartesian surface may be referred to
as an *Aplanatic Optical Surface.*

One of the most interesting portions of Huygens's " Traité
de la lumière " (written in 1678 and communicated at that time
to the Royal Academy of Science, but not published until twelve
years later) is contained in the last chapter of that book, which
in Thompson's English translation (London, 1912) is entitled
" On the Figures of the Transparent Bodies Which Serve for
Refraction and for Reflexion." Here Huygens proceeds to
discover the form of " a surface CDE which shall reassemble
at a point B, rays coming from another point A " (Fig. 1);
the " summit of the surface " being at a " given point D in the
straight line AB." With consummate skill he employs his famous
method of construction of the enveloping wave-surface, and for
the ordinary case of a refracting surface finds that " this curve
is the same that Mr. Descartes has given in his Geometry, and
which he calls the first of his Ovals." However, before setting
out to solve this problem, Huygens himself says: " For though
I do not see yet that there are means of making use of these
figures, so far as relates to Refraction, not only because of the

difficulty of shaping the glasses of Telescopes with the requisite exactitude according to these figures, but also because there exists in refraction itself a property which hinders the perfect concurrence of the rays, as Mr. Newton has very well proved by experiment, I will yet not desist from relating the invention, since it offers itself, so to speak, of itself, and because it further confirms our theory of refraction, by the agreement which here is found between the refracted ray and the reflected ray. Besides, it may occur that someone in the future will discover in it utilities which at present are not seen." The opinion which Huygens here expresses of the impracticality of "aspherical lenses" has been prevalent ever since, and perhaps that is why

FIG. 1.
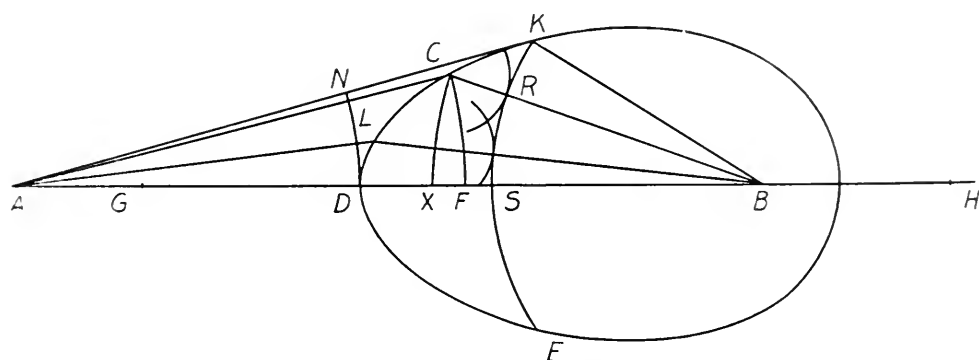
Reproduced from Huygens's "Treatise on Light."

they have received comparatively little attention. From time to time Abbe and others have revived the question in one form and another, and occasionally special types of aspherical optical surfaces have been computed and manufactured, as, for example, in the so-called "Katral" spectacle lens and in the illumination system of Gullstrand's ophthalmoscope; although let it be distinctly understood that the aspherical surfaces employed in these optical devices have nothing in common with the so-called Cartesian surfaces.

It would be both interesting and instructive to dwell more at length on Huygens's exceedingly ingenious geometrical analysis of the ovals of Descartes; but that would be beyond the scope and intention of this paper. Incidentally, of course, Huygens points out that when the rays are reflected the curve is an ellipse (Fig. 2) or a parabola (Fig. 3) in case the focus *A* is at an infinite distance. Moreover, in the case of refraction, when

one of the foci is infinitely distant, the form of the curve is an ellipse (Fig. 4) when parallel rays in air are to be brought to a real focus in glass, or an hyperbola (Fig. 5) when parallel rays in glass are to be converged to a real focus in air. It may be mentioned here that Huygens was familiar with the so-called "aplanatic points" [1] of a spherical refracting surface, which he

FIG. 2.
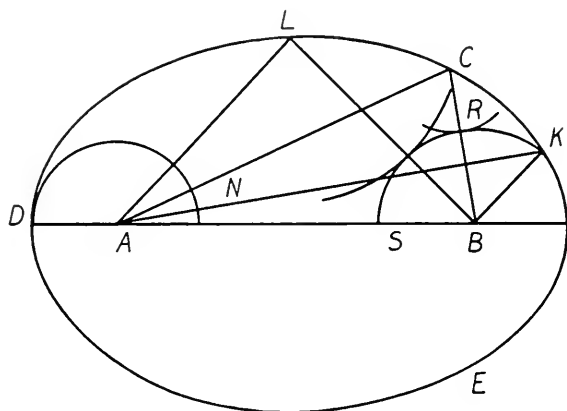
Reproduced from Huygens's "Treatise on Light."

FIG. 3.
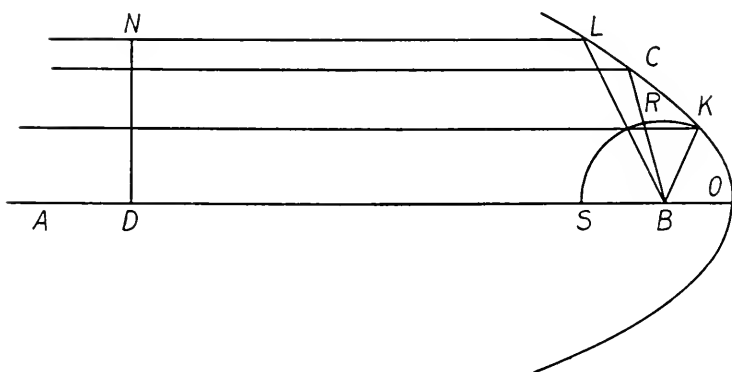
Reproduced from Huygens's "Treatise on Light."

says were known to him "a long time ago"; from which it may be inferred that Huygens was the discoverer of these points to which attention was called again many years afterwards by Thomas Young in his "Lectures on Natural Philosophy" (London, 1807). Finally, Huygens explains clearly the construction of an aplanatic lens with at least one of its surfaces aspherical and designed so that for a given pair of axial points rays of

---

[1] See, for example, Southall's "Mirrors, Prisms and Lenses" (New York, 1918), p. 512.

light would be accurately refracted by the lens from one of these points to the other.

In this historical introduction it remains only to mention that the first published paper of James Clerk Maxwell was communicated to the Royal Society of Edinburgh by Prof. James Forbes,

FIG. 4.
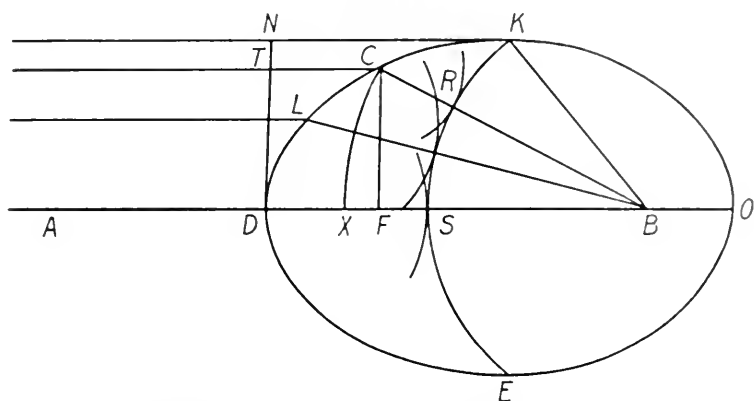
Reproduced from Huygens's "Treatise on Light."

FIG. 5.
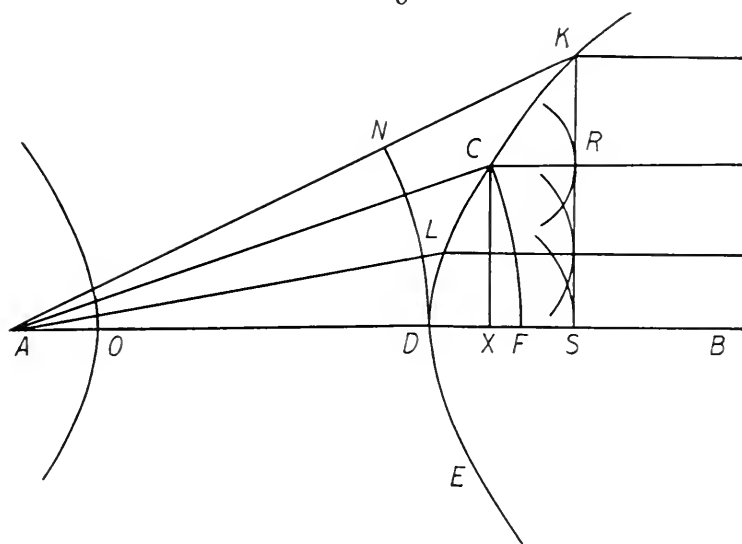
Reproduced from Huygens's "Treatise on Light."

in 1846, under the title, " On the Description of Oval Curves, and Those Having a Plurality of Foci "; wherein the author describes an ingenious method of constructing these curves with the aid of thread and pins similar to the ordinary mechanical way of drawing an ellipse. Maxwell was a schoolboy fourteen years of age when he wrote this paper. Neither he nor Professor Forbes was aware that Descartes' own process was precisely the

same in principle as that of Maxwell. A most interesting account of Maxwell's work may be found in his " Life " by Campbell and Garnett (London, 1882) ; and particularly in a " Note " appended to Chapter IV of this biography which contains a " series of propositions concerning the Ovals," with *facsimile* reproductions of young Maxwell's own drawings. The geometrical properties, as well as the optical significance of these curves, were apprehended by Maxwell with that rare ingenuity and mathematical acumen which was destined to place him in the front rank of the great physicists of the nineteenth century.

I have given the history of this subject in some little detail, because of this previous work I myself was not aware until after I had rediscovered the remarkable optical properties of the Cartesian ovals. Their story was of so much interest to me that I ventured to think others might share it also. Not much of this information is to be found in the usual text-books.

GEOMETRICAL AND ANALYTICAL INVESTIGATION.

Inasmuch as both Huygens and Maxwell (to recall only these two principal names) were, as has been stated, perfectly familiar with the optical effects of these so-called aplanatic surfaces, and since each of them in different ways and at a long interval apart has given a more or less exhaustive description of them from this point of view, any further contributions on the subject might almost seem to be a work of supererogation. The very fact that these earlier studies have fallen into comparative oblivion may serve as an argument to indicate that the practical applications are likely to be of slight value. This would perhaps be the opinion of competent authorities. However, in recent years notable advances have been made in the manufacture of optical glass both in this country and abroad; and it is now possible for opticians to obtain fairly good lenses, made of pressed glass, which are, of course, much cruder and cheaper than lenses with ground and highly polished surfaces, but which, nevertheless, are extraordinarily satisfactory and efficient for certain special limited purposes. Such lenses might be employed in flash lights, headlights on locomotives and automobiles, cheaper forms of searchlights, and condenser lenses in projection apparatus. It may, therefore, be worth while to direct attention anew to the possibility of using aspherical lenses which in Huygens's day,

at any rate, were attended with great difficulty of manufacturing. This idea was suggested to me by Dr. P. G. Nutting and led to my investigation of the matter.

The problem consists in ascertaining the form of the surface of revolution which will bend rays, either by refraction or by reflection, from a given point L on the axis to another given point L′ also on the axis; the position of the summit or vertex A being also assigned, where the straight line LL′ is to meet the surface. The foci designated here (and hereafter in this paper) by L and L′ may be " real " or " virtual," one or both, including therefore all possible cases. The step from L to A will be denoted by s, and that from A to L′ by c; thus $s = LA$, $c = AL'$, these steps along the axis being reckoned positive or negative according as they are in the same direction as the incident light or in the opposite direction, respectively. The relative index of refraction between the two media will be denoted by n; and hence if the absolute index of the first medium is put equal to unity, that of the second medium will be equal to n. When n is positive, and greater or less than unity, incident rays of light proceeding from the point L (or directed towards it, if L lies on the farther side of the surface) will be *refracted* to L′ (or as if they came from L′, when L′ lies on the nearer side of the surface towards the incident light); whereas in the special and unique case when n = −1, the light will be *reflected* in the same way from L to L′, and under these circumstances the surface in question will be an " aplanatic mirror." It goes without saying that it will be only necessary to determine the form of a meridian section of the surface of revolution. Moreover, since the central or paraxial rays constitute a portion of the wide-angle bundle of rays, the linear magnitudes denoted by s and c must be connected by the familiar abscissa-formula for the refraction (or reflection) of paraxial rays; which, expressed in terms of these symbols, will have here the following form:

$$\frac{n}{c} + \frac{1}{s} = \frac{n-1}{r} ; \qquad (1)$$

where r denotes the radius of curvature of the meridian section of the surface of revolution at its vertex A, and is to be reckoned positive or negative according as this surface is convex or concave, respectively, towards the incident light.

Naturally, the axis of symmetry LL′ or the optical axis will

be taken as the abscissa-axis of a rectangular system of coördinates. The origin of this system may be conveniently chosen at one of the points L, L' or A; suppose, therefore, we take the vertex A as origin. The problem may now be restated in terms of these symbols, thus: If a ray of light crossing the x-axis at the point L $(-s, o)$ meets the surface at a point P (x, y) where it is deflected, by refraction or reflection as the case may be, and again crosses the axis, this time at the point L' (c, o); it is required to find the locus of the incidence-point P.

The so-called ray-lengths are the steps, measured along the incident ray and the corresponding refracted (or reflected) ray, from the variable incidence-point P to the fixed points L, L'. These steps will be denoted here by l, l', thus: $l = PL$, $l' = PL'$; and are to be reckoned positive or negative according as they are in the same direction as the light goes along the ray or in the opposite direction, respectively. Evidently,

$$l^2 = y^2 + (s + x)^2 , \quad l'^2 = y^2 + (c - x)^2 . \tag{2}$$

The optical length from L to L' along the axis is equal to $(nc + s)$; whereas the optical length from L to L' *via* a point P not on the axis is equal to $(nl' - l)$, the minus sign in this expression being due to the fact that both l and l' are measured *from* P, as above defined. If these two routes are traversed by the light in the same time, then

$$nl' - l = nc + s = \text{a constant} = a \quad \text{(say)}. \tag{3}$$

This is the fundamental focal equation and is equivalent to the usual form of the equation of the ovals of Descartes, as given in the very beginning of this paper.

If l, l' are eliminated from (3) by means of equations (2), the general equation in x, y of the meridian section of the aplanatic surface may be easily derived and can be written as follows:

$$\left\{ (n^2 - 1) (x^2 + y^2) - 2 (n^2 c + s) x \right\}^2$$
$$- 4n (nc + s) \left\{ (ns + c) (x^2 + y^2) - 2 (n - 1) csx \right\} = 0. \tag{4}$$

In general, the locus represented by this integral, rational, algebraic equation of the fourth degree in x and y consists of two closed curves or ovals, one lying wholly within the other; but owing to the way in which the equation has been obtained in this fashion, that is, by squaring both sides in order to remove the radicals, one of these ovals will not be applicable to the particular optical problem which is under consideration. More-

over, the parameter n denoting the relative index of refraction actually has a very limited range of positive values, whereas it can have only one single negative value, *viz.*, the value $n = -1$.

If in equation (4) we put $y = 0$, we shall obtain an equation of the fourth degree in x whose roots are the abscissæ of the four points A, B, C and D where the axis meets the two surfaces. Thus, we obtain:

$$x \left\{ (n+1)x - 2nc \right\} \left\{ (n+1)x + 2s \right\} \left\{ (n-1)x - 2(nc+s) \right\} = 0, (y = 0);$$

that is, $x = 0$ (corresponding to the point A itself); $x = \dfrac{2nc}{n+1} = AB$

(which is the axial diameter of one of the two ovals); $x = -\dfrac{2s}{n+1} =$

AC; and $x = \dfrac{2(nc+s)}{n-1} = AD$, where CD is the axial diameter of the other oval.

The polar equation of the curve is easily obtained and affords another method of tracing its form. For this purpose it is convenient to take the focus L as the origin or pole and to denote by θ the slope-angle ALP which the radius vector LP makes with the axis; then since

$$l'^2 = l^2 + (s+c)^2 + 2l(s+c)\cos\theta, \tag{5}$$

we obtain, by combining this equation with equation (3) so as to eliminate l', the polar equation of the curve in the following form:

$$(nc + s - \rho)^2 = n^2 \left\{ \rho^2 + (s+c)^2 - 2\rho(s+c)\cos\theta \right\}, \tag{6}$$

where $\rho = -l$ denotes the radius vector LP. If in this equation we put $\theta = 0$, we find

$$nc + s - \rho = \pm n(s + c - \rho), \quad (\theta = 0);$$

and hence for the two points A and B in which the axis meets the curve:

$$\rho = LA = s \text{ and } \rho = LB = s + \frac{2nc}{n+1}$$

Putting $\theta = \pi$, we find:

$$\rho = -LC = -\frac{n-1}{n+1}s \text{ and } \rho = -LD = -\left\{ \frac{n+1}{n-1}(s+c) + c \right\}$$

which locates the vertices C and D of the other oval. However, this oval is not concerned with the optical problem of the transmission of radiant energy from L to L', which is here under

consideration. It is hardly necessary to add that the above results concerning the positions of the four vertices A, B, C and D are in agreement with those obtained previously.

The polar equation (6) may be written also as a quadratic in ρ in the following form:

$$(n^2 - 1)\rho^2 + 2\left\{(nc + s) - n^2(s + c)\cos\theta\right\}\rho$$
$$+ (n - 1)\left\{(n + 1)s + 2nc\right\}s = 0;$$

from which it appears immediately that, for given values of the parameters n, c and s, there will, in general, be two values of ρ corresponding to each value of θ.

It is easy to construct geometrically the positions of the two points P_1, P_2 on the locus corresponding to a given value of the $\underline{/L'LP} = \theta$, as follows:

With L as centre, describe two concentric circles with radii equal to a and $\dfrac{a}{n}$, where $a = nc + s$. Through L draw a straight line inclined to LL' at the given slope θ, and mark the point where this straight line meets the circle of radius a by the letter K. Draw the straight line KL' meeting the other circle in the two points Q_1 and Q_2. Draw $L'P_1$ parallel to Q_1L meeting LK in P_1; and similarly, draw $L'P_2$ parallel to Q_2L meeting LK in P_2. Then P_1, P_2 are the two required points on the locus, as may easily be proved by an inspection of the diagram as above described, with the aid of the fundamental relation given by equation (3), which is here equivalent to saying that PK : PL' = n : 1. If, for a given value of θ, the straight line KL' does not meet the circle of radius a/n, then there are no points P_1, P_2 on the locus corresponding to this value of θ; or if the straight line KL' is tangent to this circle, the two points P_1, P_2 are coincident, and in this case the given value of θ is the slope-angle of the outermost ray of the bundle emanating at L, and there will be no need of considering values of θ in excess of this limiting value.

After all the simplest way of studying the surface is by means of the fundamental focal property as expressed by equation (3). For example, differentiating this equation, we obtain:

$$dl - n \cdot dl' = 0 ; \tag{7}$$

which shows that the function $(nl' - l)$ is a minimum (or a maximum). This is obviously equivalent to Fermat's "Principle of Least Time," and in fact we might have started with this law

and obtained by integration the equation which asserts the equiva-
lence of the various optical routes from L to L′, as has been
done by many writers on mathematical optics.

When the incident ray is parallel to the axis, then $l = -(s + x)$
and hence $dl = -dx$; therefore

$$n \cdot dl' = -dx , \qquad (l = \infty) . \tag{8}$$

Or, again, if the ray after meeting the surface proceeds parallel
to the axis, then $l' = c - x$, $dl' = -dx$; and hence

$$dl = -n \cdot dx , \qquad (l' = \infty) . \tag{9}$$

If in equation (3) the constant a is equal to zero, then

$$nl' - l = 0, \qquad nc + s = 0 ; \tag{10}$$

and for this special case the oval becomes a circle; that is, the
aplanatic refracting surface is a sphere. This is the remarkable
case which Huygens said had been known to him "a long time
ago"; the pair of conjugate points L, L′ are identical with the
so-called pair of aplanatic points J, J′ of a spherical refracting
surface, which lie always both on the same side of the centre
C of the surface $(CJ = n \cdot AC, \; CJ' = \dfrac{AC}{n})$, one of these points
being a "real" focus while the other is a "virtual" focus.

In passing, it may be observed that when $n = -1$, equation (3)
becomes $l + l' = a$ constant, which, properly interpreted, includes
the well-known cases of elliptic, parabolic and hyperbolic mirrors
with the radiant point situated at one of the geometrical foci of
the conic section in question.

The case to which equation (8) applies, that is, the case
when the incident rays are parallel to the axis, is of sufficient
interest to be treated a little more in detail. When l becomes
infinite, then

$$nl' + x = \text{constant}; \; (l = \infty);$$

and since $l' = c$ for $x = 0$, the constant in this case will have the
value nc; consequently,

$$nl' + x = nc, \quad (l = \infty). \tag{11}$$

Eliminating l' by means of (3), we obtain the Cartesian equation
of the meridian section of the surface for this special case; which
may be put in the following form:

$$y^2 = \frac{2(n-1)}{n}cx - \frac{n^2-1}{n^2} x^2, \quad (l = \infty). \tag{12}$$

This is the equation of a conic section in the form

$$y^2 = 4p \, e \, x + (e^2 - 1) x^2 ,$$

where $2p$ denotes the distance of the focus from the directrix and e denotes the eccentricity. Obviously, $e^2 = \frac{1}{n^2}$; and the radius of curvature at the origin is

$$\frac{n-1}{n} c = -\frac{n-1}{n} f' ,$$

where $f' = F'A$ denotes the focal length in the second medium. (This is in agreement with the abscissa-relation for paraxial rays as given by formula (1); for if in this equation we put $s = \infty$, $c = -f'$ and solve for r, we obtain the same result as above.) The conic section will be an ellipse if $n > 1$ and an hyperbola if $n < 1$. Thus, incident rays parallel to the axis falling on a convex ellipsoidal surface of revolution and refracted from air to glass, or falling on a concave hyperboloidal surface and refracted from glass to air, will be converged to a real focus at a point L' (or F', let us designate it in this special case), such that $c = AL' = AF' = \frac{n}{n-1} r$, where $r = \frac{b^2}{a}$ denotes the radius of curvature of the ellipse and $r = -\frac{b^2}{a}$ denotes the radius of curvature of the hyperbola, each at the vertex A, and where $2a$ and $2b$ are the lengths of the two principal axes of the conic section in question. Although these two special cases were noted both by Huygens (see Figs. 4 and 5) and by Maxwell and are mentioned in some modern text-books and treatises, I think they are not generally known.[2] Dr. P. G. Nutting found this particular solution by an original and ingenious method which I had the privilege of seeing and which led me to study the general problem. It is interesting to remark that Kepler in his famous *Dioptrice* gives a proposition to show that the surface which will converge parallel rays in glass

---

[2] This article was already being printed when the author happened to see a letter in *Nature* (Feb. 16, 1922; vol. 109, pp. 205, 206) signed A. Mallock; in which, speaking of the advantage of aspherical lenses for microscopes, he alludes, by way of illustration, to the problem of finding "the form of a planoconvex lens which will convert spherical waves originating at [a point] O into a parallel beam;" and gives the following solution:

"Let the [required] convex surface of the lens cut the principal axis O X at A, and let the refractive index of the material be μ. The form of the surface is determined by the relation O A $+ \mu \cdot$A N $=$ O P [where P is a point on the meridian section of the surface and N is the foot of the ordinate at P]. Elementary algebra shows that the curve P A is a hyperbola the asymptotes of which make angle $\tan^{-1} \sqrt{\mu^2 - 1}$ with the axis of the lens."

to a point in air is (as he says) " approximately hyperbolic " ;[3] and the curious thing about it is that Kepler obtained this result,

FIG. 6.
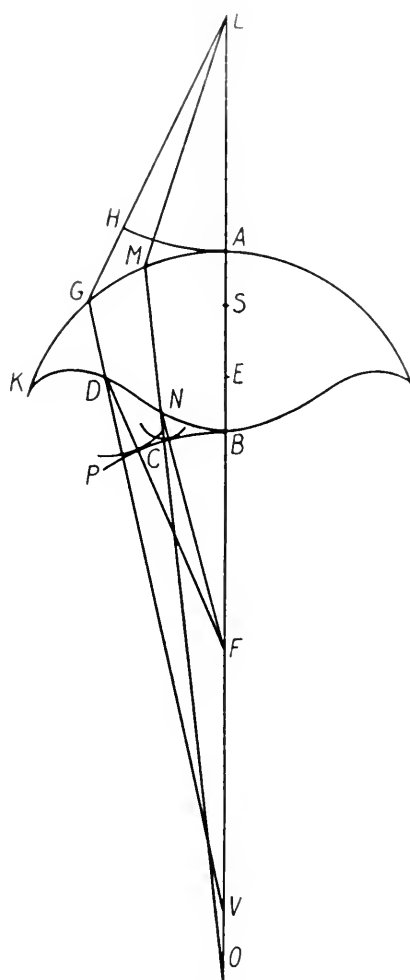
Reproduced from Huygens's "Treatise on Light."

and indeed many of the properties of lenses and other optical contrivances, without knowing the true law of refraction.[4]

Huygens, in his " Treatise on Light," after having discussed the forms of the various ovals of Descartes, proceeds to show how the method of equal optical lengths which he employs " leads

---

without difficulty to the finding of the curves which one side of the glass lens requires when the other side is of a given figure, not only plane or spherical or made by one of the conic sections (which is the restriction with which Descartes proposed this problem, leaving the solution to those who should come after

FIG. 7.
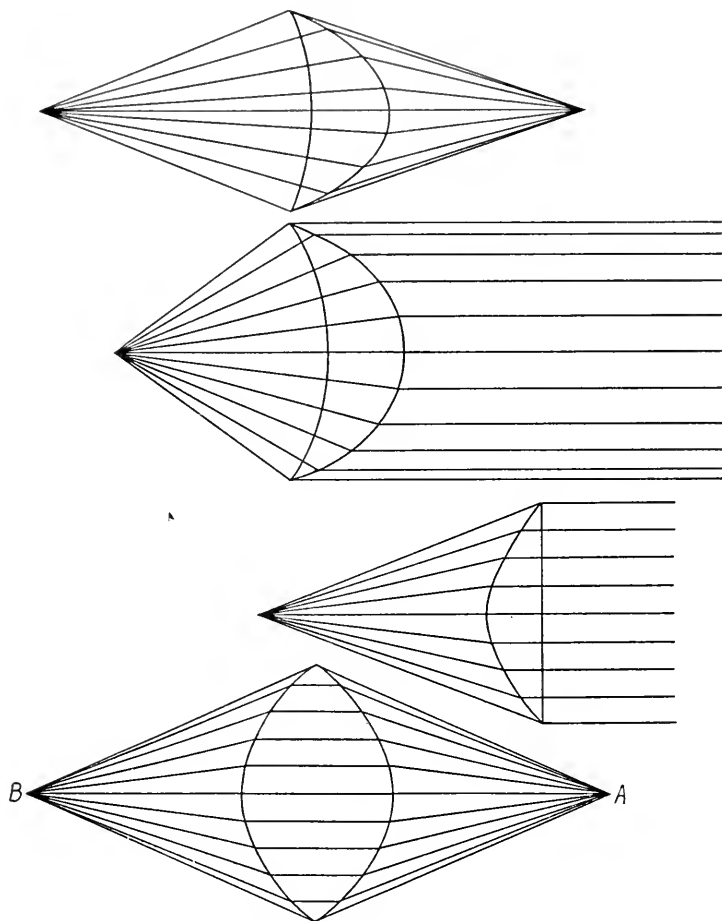
Reproduced from Campbell and Garnett's "Life of Maxwell."

him), but generally any figure whatever; that is to say, one made by the revolution of any given curved line to which one must merely know how to draw the straight lines as tangents." The accompanying diagram (Fig. 6) which is reproduced from Huygens's work shows schematically the form of such an aplanatic lens, in which, the first surface AK being prescribed, " the outline ·BDK, which constitutes the other surface, shall be such that the path of the light from the point L to the surface AK, and from thence to the surface BDK, and from thence to the point F, shall be traversed everywhere in equal times, and in each

case in a time equal to that which the light employs to pass along the straight line LF of which the part AB is within the glass."

The diagram (Fig. 7), which is a *facsimile* reproduction of some of Maxwell's drawings as given in Campbell and Garnett's book, referred to above, shows certain obvious forms of aplanatic lenses. A glass lens designed to converge parallel rays to a real focus may be made, for example, either in the form of a convex meniscus lens with a spherical surface on the side next the focus (which is at the centre of the sphere) and an elliptic spheroidal surface on the other side, or in the form of a planoconvex lens with an hyperbolic spheroidal curved surface, as represented in the two middle diagrams of Fig. 7. Again, a symmetrical convex glass lens with hyperbolic spheroidal faces might be employed to transmit light-energy from a given point on one side of the lens to a point at an equal distance on the other side, as indicated in the lowest diagram in Fig. 7. The lens-thickness is immaterial, except in so far as the aperture of the system is dependent on this factor; but, as a matter of fact, for a large aperture the thickness will generally have to be rather excessive, it seems to me; which would probably preclude these forms from being used practically for flash-light systems, head-lights, condenser systems, etc.

In connection with the aplanatic optical surface, as defined by the fundamental focal relation (3) above, certain other general relations are also of sufficient interest to be mentioned here. Let $\theta = \angle\mathrm{ALP}$ and $\theta' = \angle\mathrm{AL'P}$ denote the slopes of a ray before and after refraction at the surface at P; and let ϕ denote the angle which the incidence-normal makes with the axis; and, finally, let α, α' denote the angles at P which the ray makes with this normal before and after refraction, so that according to the law of refraction:

$$n \cdot \sin \alpha' = \sin \alpha. \tag{13}$$

There are obvious geometrical relations between these angles, namely:

$$\varphi = \alpha - \theta = \alpha' - \theta'. \tag{14}$$

It should be remarked that the angles here indicated are all *acute angles* (or at any rate cannot have any greater absolute value than $\pi/2$) and are to be reckoned positive or negative according as the sense of rotation is counter-clockwise or the reverse, respec-

tively. The slope-angles denoted by θ, θ' may be more precisely defined in terms of the linear magnitudes, thus:

$$\sin \theta = -\frac{y}{l}, \cos \theta = -\frac{s+x}{l}$$

$$\sin \theta' = -\frac{y}{l'}, \cos \theta' = \frac{c-x}{l'}; \tag{15}$$

where x, y denote the coördinates of the point P referred to a rectangular system of axes with the origin at the vertex A.

Combining (13) and (14) so as to eliminate the angles of incidence and refraction, α and α', another perfectly general relation for the refraction of a ray at any surface of separation of two isotropic optical media may be obtained as follows:

$$\tan \varphi = \frac{\sin \theta - n \sin \theta'}{\cos \theta - n \cos \theta'} \ . \tag{16}$$

And if θ and θ' are eliminated from the right-hand side of this expression by means of formulæ (15), it becomes:

$$\tan \varphi = -\frac{(nl - l')\,y}{n\,(c-x)\,l+(s+x)\,l'}. \tag{17}$$

Moreover, since

$$\frac{dy}{dx} = - \cot \varphi , \tag{18}$$

the angle φ may be eliminated by combining (17) with (18), so that the preceding relation is equivalent to the following general condition:

$$nl \left\{ \left(y \frac{dy}{dx} \right) - (c-x) \right\} = l' \left\{ \left(y \frac{dy}{dx} \right) + (s+x) \right\}. \tag{19}$$

Now if the surface is to be aplanatic, the condition (3) must be imposed; hence, squaring both sides of the general equation (19) and eliminating l^2 by means of the special equation (3), we derive an equation of condition which must be satisfied by any aplanatic surface, namely:

$$A\,(s+x)^2 + B\,(s+x) + C = 0 , \tag{20}$$

where for brevity the symbols A, B and C have been introduced to denote the following expressions:

$$A = n^2 z^2 - l'^2, \quad B = -2 \left(y \frac{dy}{dx} \right) l'^2,$$

$$C = n^2 y^2 z^2 - l'^2 \left(y \frac{dy}{dx} \right)^2, \tag{21}$$

and where

$$z = \left(y \frac{dy}{dx} \right) - (c - x) .\tag{22}$$

Anyone who will take the trouble may convince himself that
the condition (20) is satisfied by the general equation of the
aplanatic surface as given by (4); but it is a laborious task, as
the writer can testify.

One other general formula for the refraction of a ray at
an optical surface of any form may be given here; which I think
will be found useful. Suppose a ray of light is refracted at a
point P on a surface separating two media whose absolute indices
of refraction are n and n'; and let L designate the position of a
point lying anywhere on the straight line which corresponds to the
incident ray; similarly, let L' designate the position of a point
lying anywhere on the corresponding straight line determined by
the refracted ray. Connect the two arbitrary points L, L' by a
straight line which meets the refracting surface in a point to be
designated here by A. Evidently,

$$l' \cdot \sin \theta' = l \cdot \sin \theta ,\tag{23}$$

where the symbols θ and θ' denote the acute angles ALP and
AL'P, respectively, and $l = $ PL, $l' = $ PL'.

Draw the normal to the surface at the point P, and let the
point where this normal meets the straight line LL' be designated
by G. Put $g = $ GL, $g' = $ GL' to denote the steps from G to L and
to L', respectively. Then

$$g : \text{PG} = - \sin \alpha : \sin \theta, \quad g' : \text{PG} = - \sin \alpha' : \sin \theta' ,$$

where α, α' denote the angles of incidence and refraction. Since
$n \cdot \sin \alpha = n' \cdot \sin \alpha'$, the two proportions above may be combined
into the following equation:

$$n'g' \cdot \sin \theta' = ng \cdot \sin \theta ;$$

and hence according to (23) above:

$$\frac{n'g'}{l'} = \frac{ng}{l} .\tag{24}$$

This is an invariant relation for refraction which has long been
known for the special case when the refracting surface is spheri-
cal;[5] but which has never to my knowledge been expressed as
generally as in the form given here.

As an illustration of the use of formula (24), it may be

---

[5] See, for instance, Southall's "Mirrors, Prisms and Lenses" (New York,
1918), p. 518.

applied to derive the general equation of condition given by (20). Suppose the plane of incidence is taken as the plane of a system of rectangular axes with its origin at the point A where the straight line LL' (x-axis) meets the refracting surface. Let the foot of the ordinate of the incidence-point P be designated by D, so that $x = AD$, $y = DP$, and $y \dfrac{dy}{dx} = DG$. Putting $m = LD$, we may write: $l^2 = y^2 + m^2$; and since

$$g = -\left(m + y\frac{dy}{dx}\right)$$

we obtain according to equation (24):

$$n'^2 g'^2 (y^2 + m^2) = n^2 l'^2 \left(m + y\frac{dy}{dx}\right)^2 ;$$

which may be arranged as a quadratic in m as follows:

$$(n'^2 g'^2 - n^2 l'^2) m^2 - 2n^2 l'^2 \left(y\frac{dy}{dx}\right) m$$

$$+ n'^2 g'^2 y^2 - n^2 l'^2 \left(y\frac{dy}{dx}\right)^2 = 0.$$

This equation is precisely equivalent to (20); as may be seen by writing $(s + x)$ in place of m, n in place of n'/n, and $-z$ in place of g'.

New York, N. Y.
    March 1, 1922.

The Centenary of the Discoveries of Ampère. (*Le Matin*, Nov. 25 and 26, 1921.)—On November 24, 1921, in the great amphitheater of the Sorbonne, France celebrated in a worthy manner the scientific achievements of her great son whose name has been given to the unit of electric current. The President of the Republic presided and addresses were made by Paul Appell, Paul Janet, Raynauld, Legouez and Boucherot. The tribute of the United State was given —and in the French language—by Dr. C. O. Mailloux, member and official delegate of The Franklin Institute, Philadelphia.

The four thousand persons present found interest in a table a metre square, on which was a complex of rods and wires. Though the humble product of a village locksmith it was none the less from the laboratory of Ampère to which so many of the applications of electricity can be traced.

The ceremonies were continued the next day at the Conservatoire des Arts et Metiers under the charge of Painlevé. He emphasized the discoveries made in the art of telegraphy in France in succession to the work of Ampère.

                                                            G. F. S.

PHOTOGRAPHY OF BULLETS IN FLIGHT.*

BY

PHILIP P. QUAYLE.

Assistant Physicist, National Bureau of Standards.

THE study of the characteristics of a bullet in flight, together with its attending sound waves, is facilitated if instantaneous photographs of the phenomena are available. It is the purpose of this paper to outline the procedure by which such photographs are easily obtained.

The timing of mechanism employed in the apparatus to be

Fig. 1.

R = Relay
V = Potential Regulator
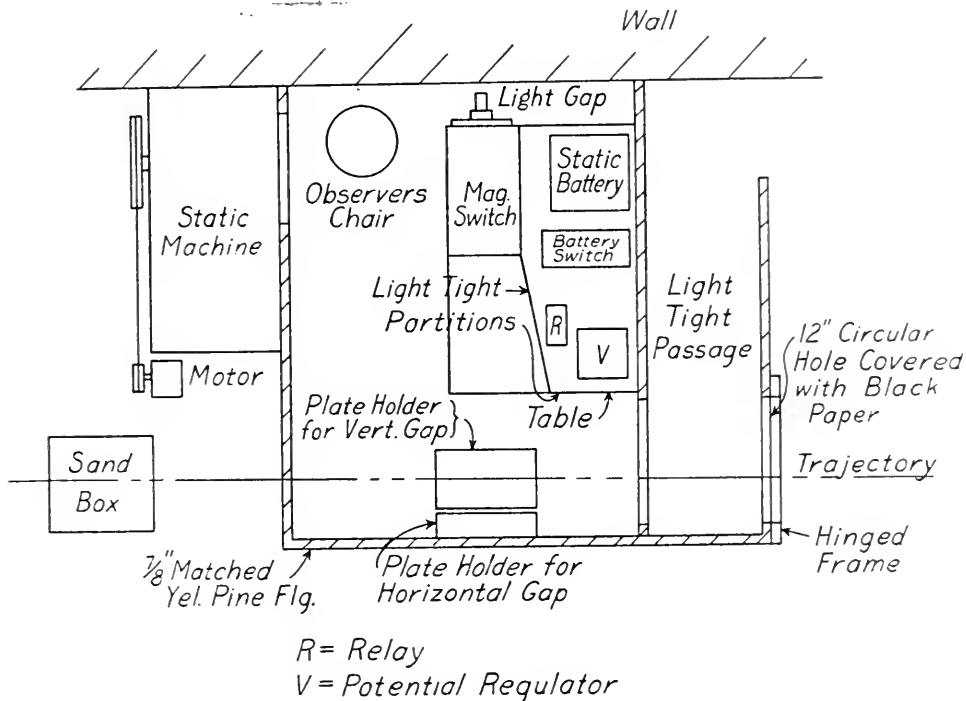
described in this paper is thought to be unique in that the bullet is not interfered with in any way and its photograph is obtained free from disfiguration by wires or other portions of the apparatus.

It is known that any mass moving through the atmosphere with a speed equal to or greater than that of sound causes a high compression of the air immediately in its front. This compression

---

* Communicated by Dr. E. A. Eckhardt.

radiates spherically from that point with the speed of sound. At the same time the mass from which the compressional wave is propagated is moving forward with its own speed, and if this is greater than that of sound, the resultant wave is not spherical but conical.

If such a wave is projected upon a photographic plate by means

FIG. 2.

Plan View

Elevation View

of an instantaneous point source of light, the phenomenon is sharply depicted. Light from the point source in passing tangent to the wave must go through a layer of air much denser than the adjacent atmosphere. This dense layer of air causes refraction effects similar to those of a lens, and forms the image of the sound wave on the plate.

In the apparatus with which the photographs were obtained this sound wave controls the time of functioning of the spark, by means of an interrupter. The electrical circuit containing the spark gap had a natural frequency of oscillation of 4×10^{-6} seconds and was critically damped.

In general, the order of operation is as follows: The bullet, after leaving the rifle on its way to the small house in which the photographing is actually done, passes in front of an interrupter. The impinging of the sound wave upon the diaphragm of the interrupter automatically trips a switch inside of the apparatus house.

The bullet, while passing the photographic plate, is projected upon it by the spark controlled by this switch.

It is desirable to have the apparatus uniform in its operation

FIG. 3.
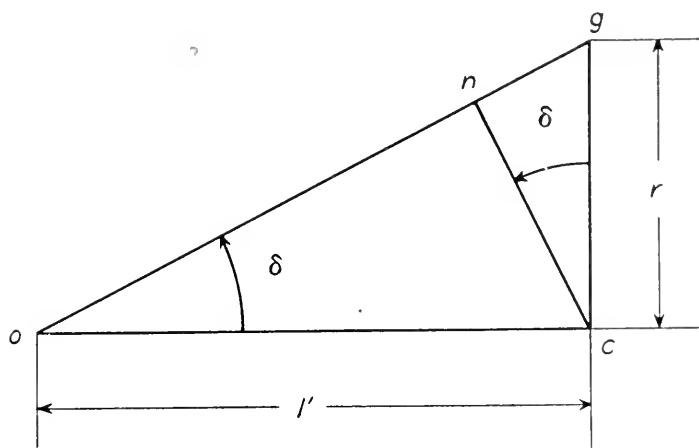
and automatic as far as possible. To this end certain controls have been constructed which limit the potential on the static battery where the charge, which causes the photographic spark, is stored. This static battery is charged by means of a large two-revolving-plate induction machine which is motor driven. A potential regulator was constructed and also a charging switch for the static battery. In operation the potential regulator was set off when the potential across the static battery was sufficiently high. The functioning of the regulator tripped the static battery switch, thus disconnecting the charging machine and short circuiting its terminals. The battery switch also turns on a signal light located outside the apparatus house as a signal to the rifle operator to fire. If the rifle is fired promptly at the signal, the operation of the apparatus is quite uniform.

ARRANGEMENT OF APPARATUS.

The bullet photography apparatus, except the interrupter, is entirely enclosed in a wooden house about 6 x 8 feet, entrance to which is obtained through the light-tight passage (see Fig. 1).

FIG. 4.
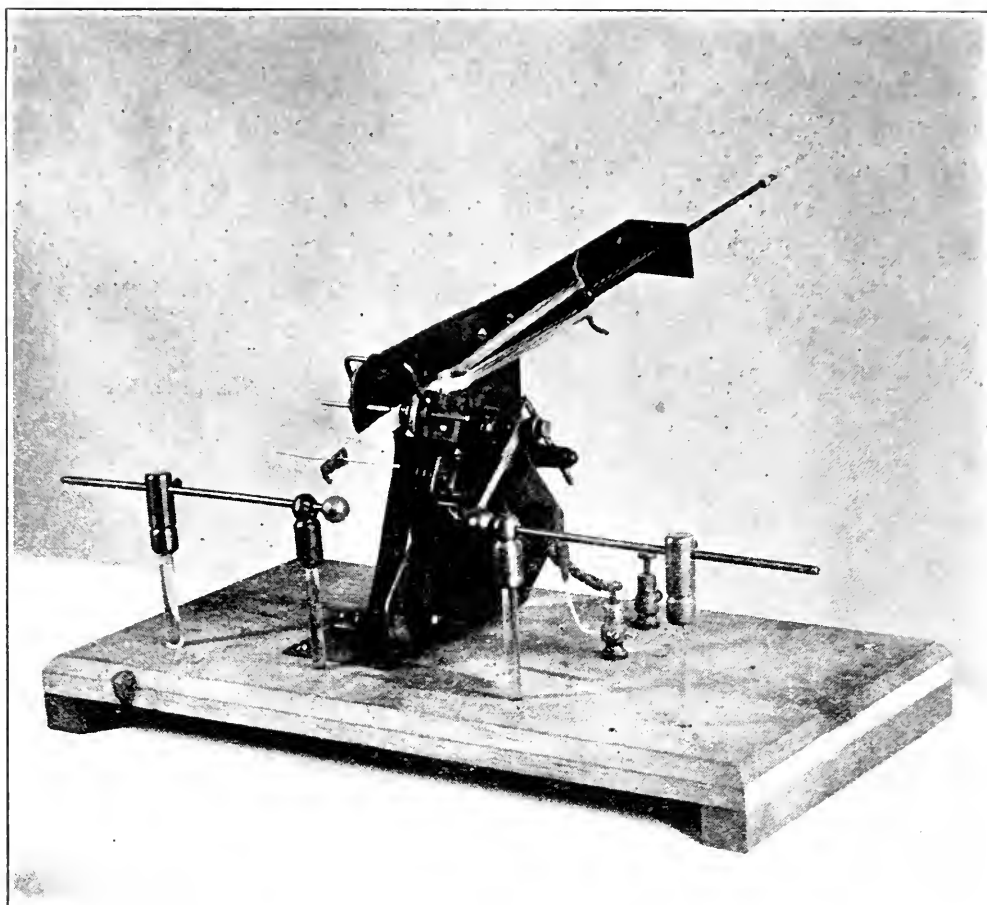
Magnetic switch which sets off the photographing spark.

FIG. 5.
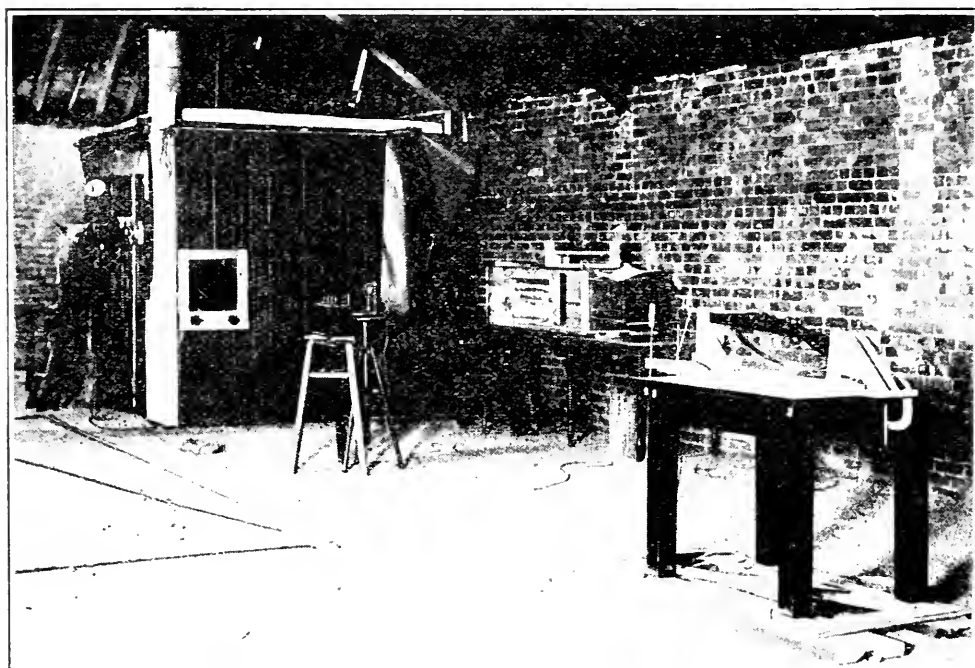
The laboratory in which the bullet photographs were made.

The magnetic switch which sets off the photographing spark is built into the frame holding the horizontal light gap, and this together with the large static battery, relay, battery switch, and potential regulator, is mounted on the table as indicated, and

FIG. 6.
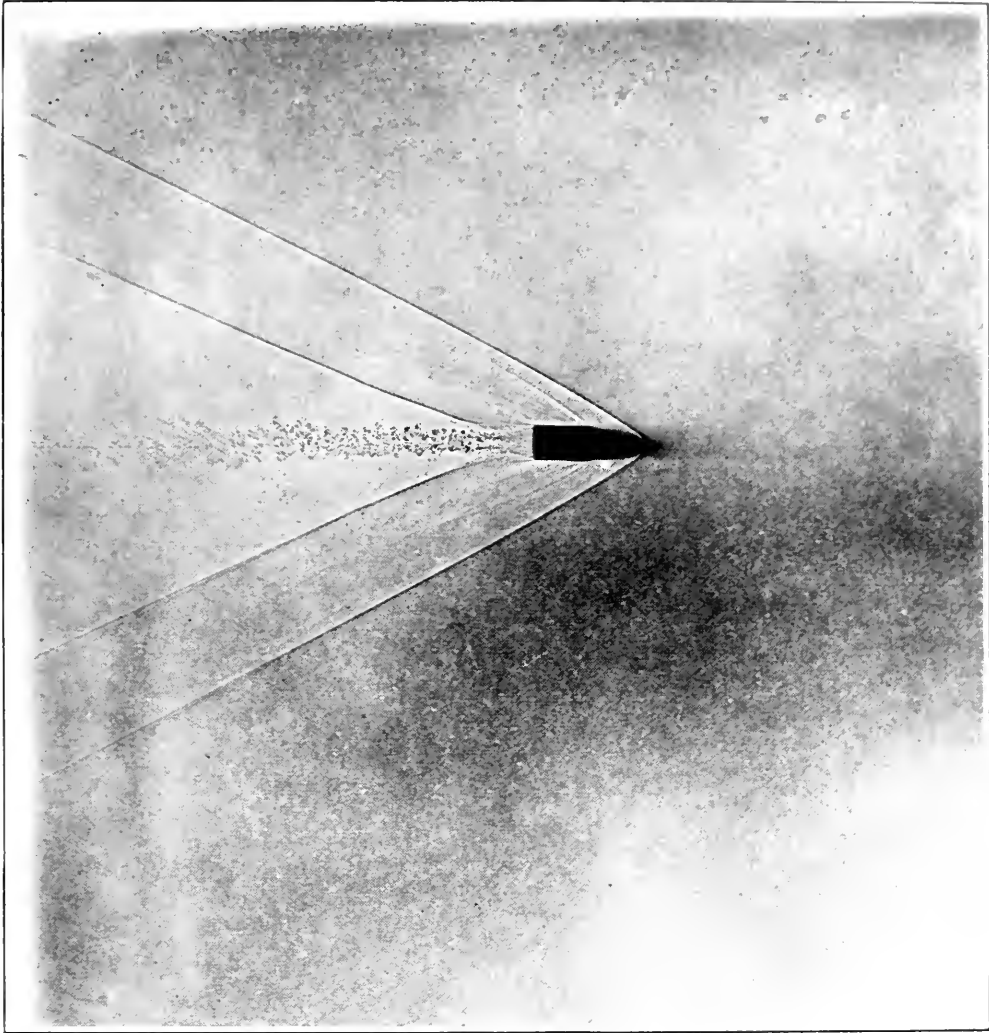
Modified Spitzer bullet, speed 3000 feet per second.

screened from the photographic plates by the light-tight partition. All the surfaces are painted a flat black. Directly in front of the horizontal light gap and distant from it 6.55 feet, a frame for the 11″ x 14″ plate holder is mounted. A similar arrangement in a vertical direction enables the apparatus to take two pictures of the same bullet, a plan and elevation. This is found to be very

FIG. 7.
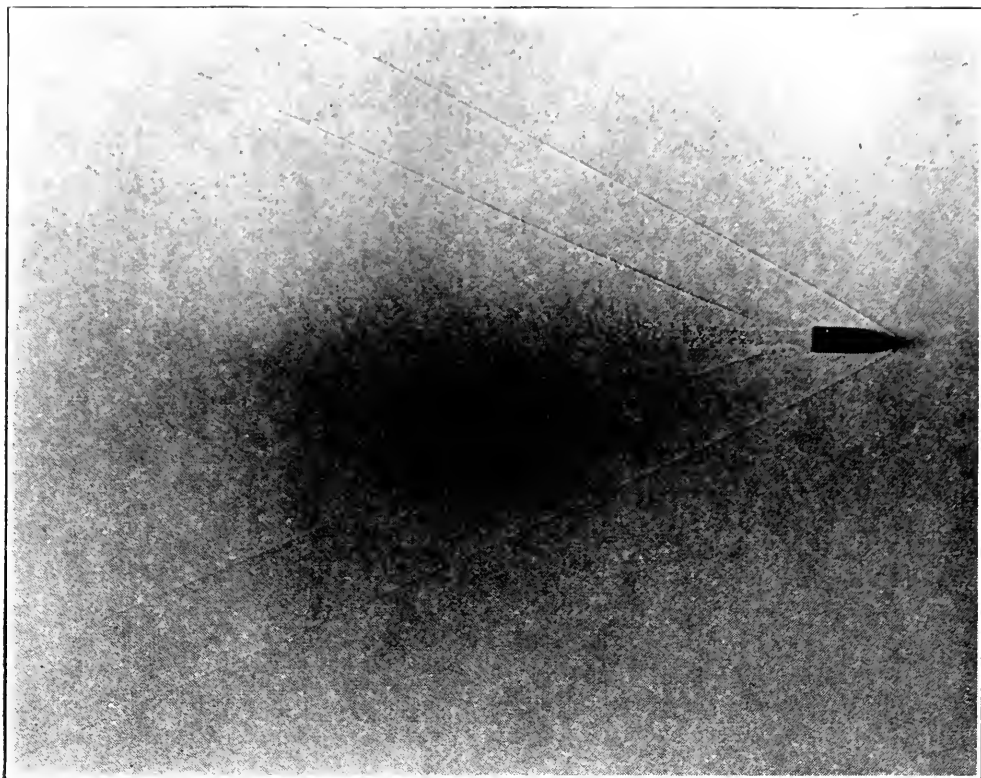
30-calibre normal Spitzer bullet.   Speed 2700 feet per second.

FIG. 8.

Boat-tailed bullet beginning to tumble.

useful in investigating new types of ammunition which have a tendency to tumble.

THE OPERATION OF THE APPARATUS.

The operation of the apparatus is as follows:

The operator opens the magnetic switch and closes the battery switch. As he walks out he turns out the lights and draws the slides of the plate holders in use. He then loads the rifle, makes any correction necessary in the aiming and closes the motor switch

FIG. 9.
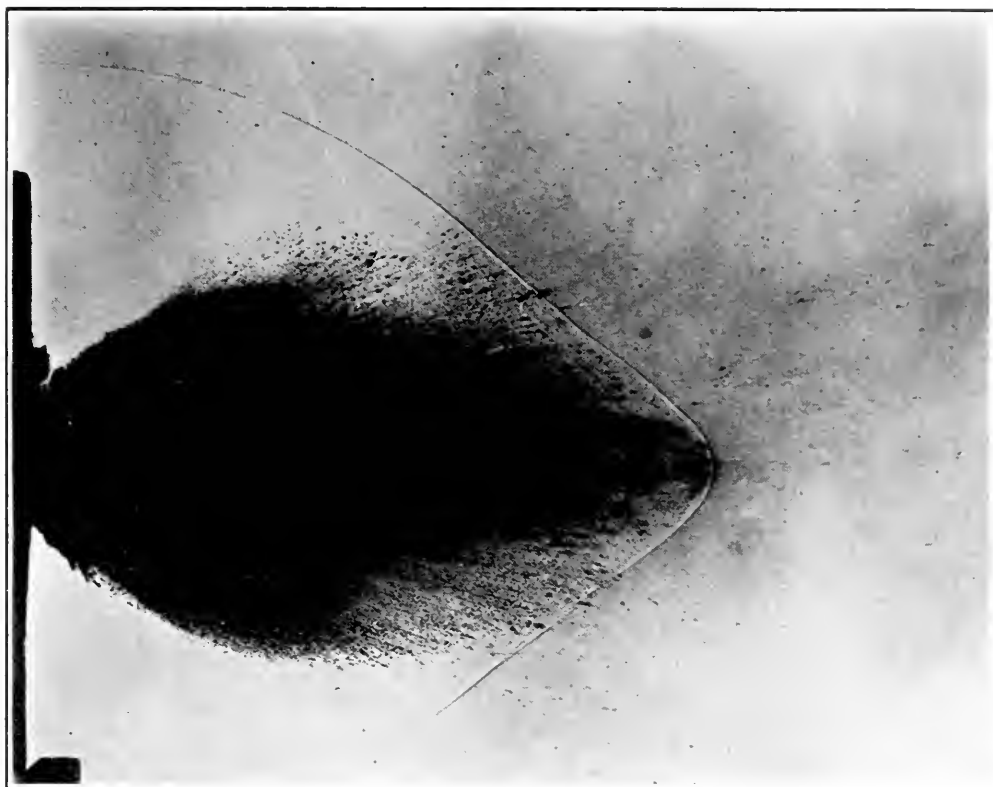
Flat-nose Spitzer bullet after going through 1-¾″ plaster-of-Paris. Note that the jacket has been torn off and is following behind the bullet.

which is mounted on the rifle table. He takes up the slack in the rifle trigger, and as soon as the signal light comes on, fires. The motor switch is then opened, the slides replaced in the plate holders, and the plates are ready to be taken to the dark room for developing.

PRELIMINARY ADJUSTMENT.

In case nothing is known of the speed of the bullets to be investigated, a piece of ordinary wire screen (see Fig. 13) or paper is placed in the line of fire in front of the plate, and if its image

is punctured when the plate is developed, evidently the bullet
had gone past the plate before the spark occurred. Since the lag
of the apparatus is constant, the interrupter must be moved back
from the plate.

FIG. 10.
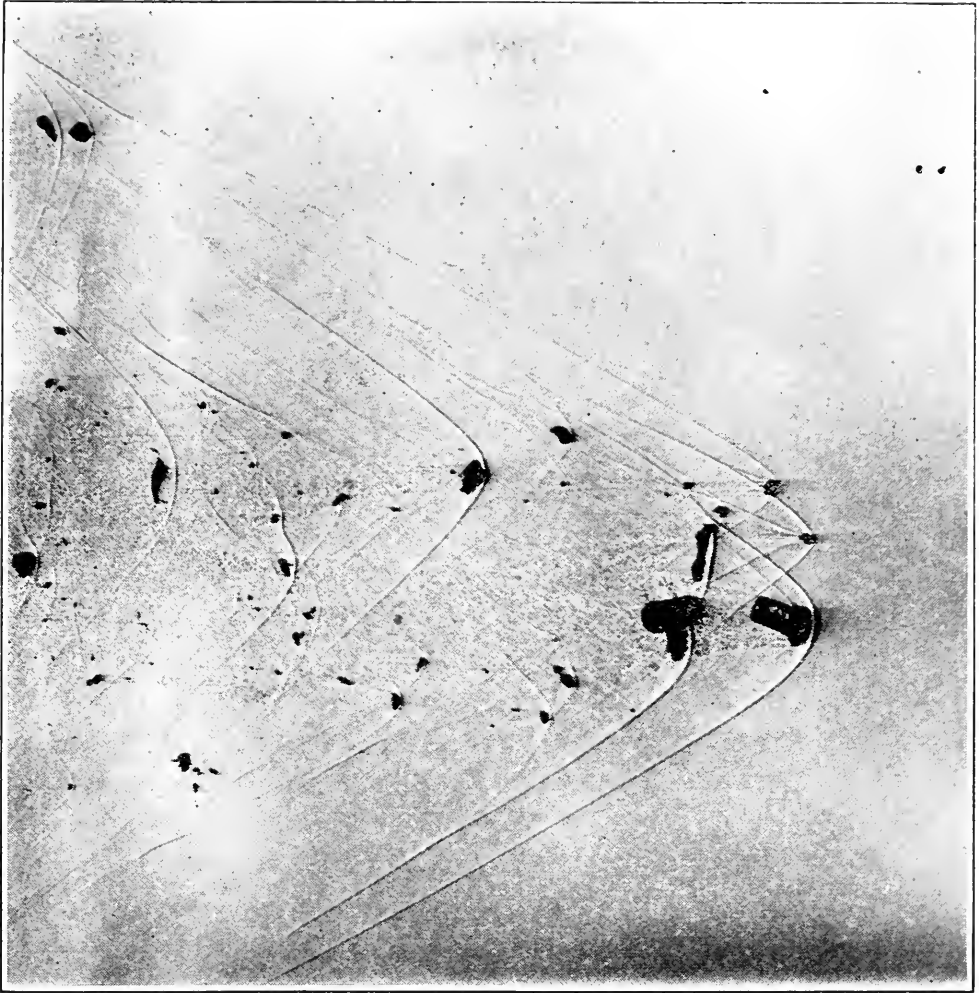
Flat-nose Spitzer bullet after going through ¾″ hard maple board. Note that the jacket
has been torn off and is following behind the bullet.

VISUAL ADJUSTMENT.

When the adjustment of the apparatus is such that the bullet
lies anywhere within the space illuminated by the spark it stands
out sharply, and not only the bullet but also its shadow are sharply
defined and visible to the most inexperienced observer. A strip of
white cardboard when placed in the position normally occupied

by the plate makes an excellent background against which the bullet and its shadow contrast sharply.

When the visual method of adjustment is used an observer calls off the successive shots and the necessary changes in the interrupter distance are made until most of the bullets are seen in front of the plate as the spark illuminates it.

THE RELATION OF SPEED OF THE BULLET TO THE CONICAL SOUND WAVE.

Any bullet having a speed greater than that of sound propagates from both its nose and base a conical sound wave. These two waves are coaxial and the corresponding elements of their surfaces are parallel except in the immediate vicinity of the bullet; but due to the projection they diverge somewhat on the photographic plate.

At the apex of the cone the sound wave is travelling with the velocity of the bullet, while a short distance back from this point the wave slows down to the velocity of sound in air at the time of the experiment. The greater the velocity of the bullet the smaller the angle at the apex of the cone.

Since the distance of the light gap from the photographic plate is but six and one-half times the diameter of the largest portion of the conical sound wave photographed, a slight error would be made if the wave as photographed on the plate were assumed to faithfully represent the wave in air; for while the axis of the wave is projected in direct proportion to its length, it is evident that its radius is not. The radius of the projected element of the conical sound wave is not in a plane parallel to that of the photographic plate—hence the error.

It will be evident that if the true angle formed by the axis of the conical sound wave in air and that element of its surface which is projected upon the photographic plate were known, the velocity of the bullet producing the wave could be determined.

A formula giving these data will now be derived for a speed of sound equal to S feet/sec.

DISCUSSION OF THE PROJECTION OF THE CONICAL SOUND WAVE UPON THE PHOTOGRAPHIC PLATE.

Due to geometrical reasons, the image of the conical sound wave as projected upon the photographic plate is somewhat distorted.

Referring to Fig. 2, Z is the plane of the photographic plate,

FIG. 11.
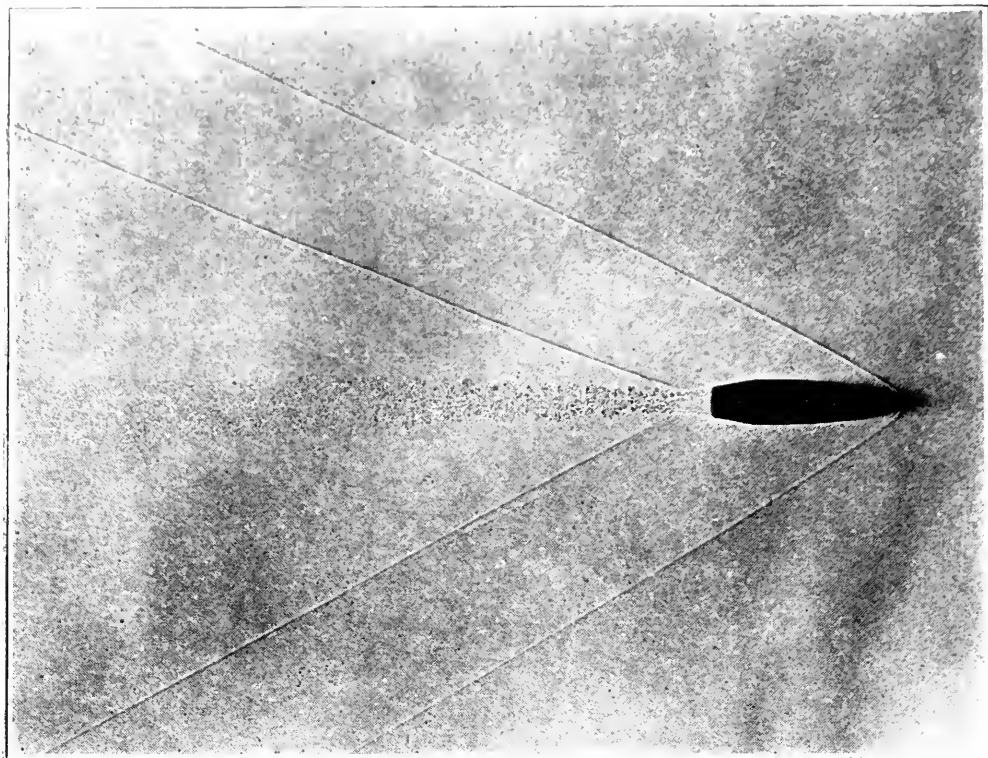
30-calibre boat-tailed bullet.

FIG. 12.
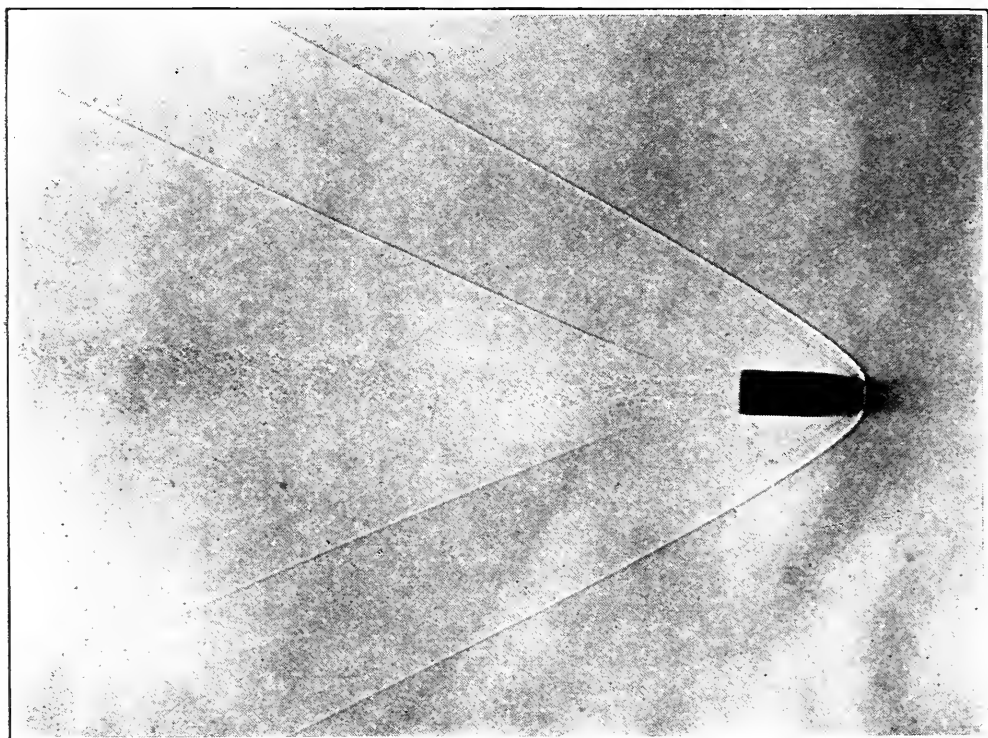
Flat-nose Spitzer bullet.

FIG. 13.
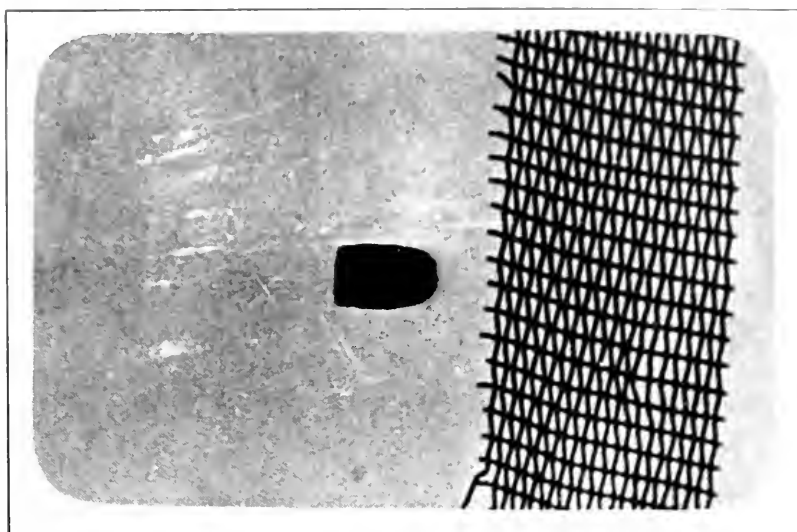
22-calibre bullet; no sound wave since the speed is approximately 900 feet per second which is less than that of sound.

FIG. 14.
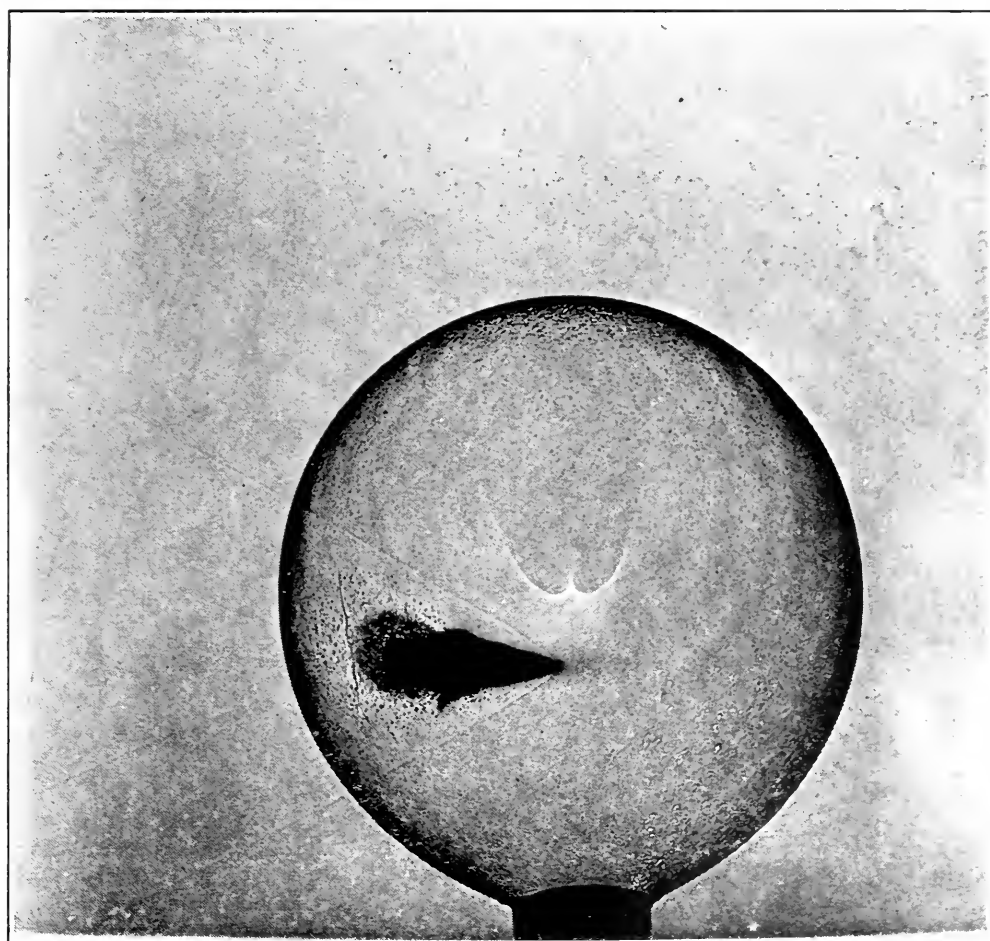
30-calibre Spitzer bullet entering soap bubble.

and Y and X are parallel planes passing through the trajectory and the light gap, respectively. From Fig. 2 it will be seen that l is the projection upon the photographic plate of that portion OC of the trajectory, which is also the axis of the conical sound wave o u w, see plan view, Fig. 2.

It is to be noted that l is measured from d, the intersection of

FIG. 15.
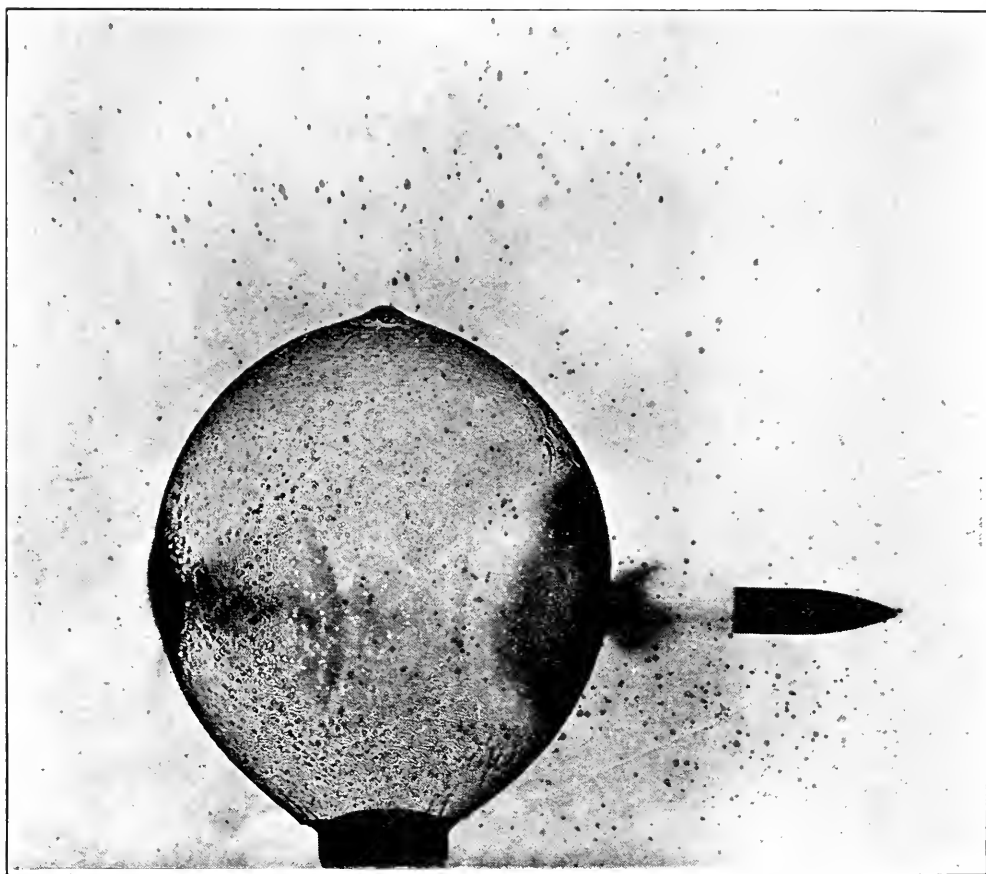
30-calibre Spitzer bullet after going through soap bubble.

the wave front produced as straight lines beyond the nose of the bullet, to the intersection of the plane of the base of the right circular cone with the photographic plate. At the point e, elevation view, $\frac{h}{2}$ is measured perpendicular to dc; a is the distance of the plane of light gap X from that of the trajectory Y, and b is the distance of the plane of the trajectory from the photographic plate Z.

It is desired to find an expression for the true angle formed by the element og of the conical sound wave, and the axis oc. It will be evident that the work will be greatly simplified by taking the cutting plane perpendicular to the axis oc, its trace in the plan view being the line scc.

From Fig. 2, it will be seen that:

$$m = b \tan \theta \text{ and } l' = l - m \therefore l' = l - b \tan \theta$$

$$\theta = \tan^{-1} \frac{l}{a+b} \qquad \phi = \tan^{-1} \frac{h}{2(a+b)}$$

$$r = a \sin \phi = a \sin \tan^{-1} \frac{h}{2(a+b)}$$

It will be seen that l' and r are respectively the base and altitude of the triangle formed by the axis oc of the conical sound wave and that element og of its surface which is contained in the tangent plane passing through the light gap s. Let this angle be δ (see Fig. 3), then

$$\tan \delta = \frac{r}{l'}$$

$$\text{or } \tan \delta = \frac{a \sin \phi}{l - b \tan \theta}$$

$$= \frac{a \sin \tan^{-1} \frac{h}{2(a+b)}}{l - b \frac{l}{a+b}}$$

Since l' is proportional to the velocity of the bullet and nc to the velocity of the sound in air at the time the plate is exposed, it follows that the velocity of the bullet in terms of the speed of sound is given by

$$V = \frac{l'}{n c} S$$

Where S = the speed of sound in air at the time the plate is exposed.

From Fig. 3 it will be seen that $nc = l' \sin \delta$, supplying this value in the velocity equation gives

$$V = \frac{l'}{l' \sin \delta} S = \frac{S}{\sin \delta}$$

In order to obtain values of V in terms of S for different values of $\sin \delta$ it is first necessary to solve

$$\tan \delta = \frac{a \sin \tan^{-1} \frac{h}{2(a+b)}}{l - b \frac{l}{a+b}}$$

for delta. It is to be noted that a and b are held constant for any given set up.

By supplying in the formula

$$V = \frac{S}{\sin \tan^{-1} \left[\dfrac{a \, \sin \, \tan^{-1} \dfrac{h}{2 \, (a + b)}}{l - b \, \dfrac{l}{a + b}} \right]}$$

a table could be computed for different vaules of h while l is held constant. It is to be noted that for every different l a new table must be computed if the above formula is used. As previously pointed out, l must be measured from the point of the cone to the intersection of the plane of the base of the right circular cone with the photographic plate.

In the set-up with which the photographs were obtained the light gap is directly opposite the centre of the plate. Therefore, when the bullet is photographed in the centre of the plate the light gap lies on the perpendicular to the sound wave axis erected at its apex.

In this position there is no error of projection, for the elements of the conical sound wave which are projected on the plate are then both contained in a plane which passes through the wave axis and is parallel to the plate.

The utilization of the bow wave for triggering the spark and the type of springs used in the magnetic switch were suggested by Dr. D. C. Miller, in charge of the Physical Laboratory at Case School of Applied Science, where the work was done.

The Application of the Ultra-micrometer to the Measurement of Small Increments of Temperature. W. SUCKSMITH. (*Phil. Mag.*, January, 1922.)—Two oscillating valve circuits are so joined up that a variation in the capacity of a condenser will cause a change in the number of beats per second produced by the interference of a note from a tuning fork with the heterodyne note in a telephone receiver connected in the circuit. The condenser consists of two parallel metal plates, one of which is carried by a metal rod whose change of temperature is to be determined. With a knowledge of the constants of the apparatus it is possible to detect a change of temperature of one-sixteen thousandth of a degree Centigrade, or a change of length of one two-hundred millionth of an inch. The expansion coefficient of copper was measured by raising the temperature a single degree.   G. F. S.

A PRECISION ROTATING SECTOR: APERTURE VARIABLE AND MEASURABLE WHILE IN MOTION.*

BY

A. H. PFUND, PH.D.

Associate Professor of Physics, Johns Hopkins University.

THE validity of Talbot's law has been so amply established by the work of Brodhun, Hyde and others, that the rotating sector has attained widespread use in photometry. This is not surprising in view of the fact that the simple rotating sector, as a means for varying the intensity of light, possesses the following advantages:

1. It is an " absolute " instrument.

2. It is non-selective and is, hence, equally applicable to work in the infra-red, visible and ultra-violet spectrum.

3. It does not modify the character of the incident light—as is the case with polarization photometers.

4. It possesses a large field of view that is uniformly illuminated.

5. It makes for compactness of construction—in contrast to the application of the " inverse-square law."

In view of these cardinal virtues it is not to be wondered at that numerous attempts have been made to transform the simple rotating sector into an ideal instrument by making the angular opening both variable and accurately measurable while the sector is in motion. Noteworthy attempts in these directions have been made by Abney, Brodhun, Keuffel and others. While the sector of Brodhun swings the light-beam over a stationary and variable aperture by means of glass rhombs (thus sacrificing non-selectivity) the others, as a rule, have a lever whose motion is transmitted to the sectors by means of clutches, gears, etc. The angular opening is read off a scale over which the lever moves. In consequence of unavoidable " lost motion," the scale reading thus obtained does not yield the angular opening with precision. Recognizing this difficulty, some investigators have chosen the course of stopping the sector in order to read the angular opening from the scale engraved on the sectors themselves. Due to inertia effects which

---

* Communicated by Joseph S. Ames, Ph.D., Associate Editor.

assert themselves when the sectors are stopped, the angular opening as read is not that which existed while the sector was in motion—hence this mode of procedure also does not yield accurate results.

The instrument developed by the writer overcomes these difficulties. By means of a simple stroboscopic device, the angular opening is read off the scale engraved on the sectors themselves.

Fig. 1.
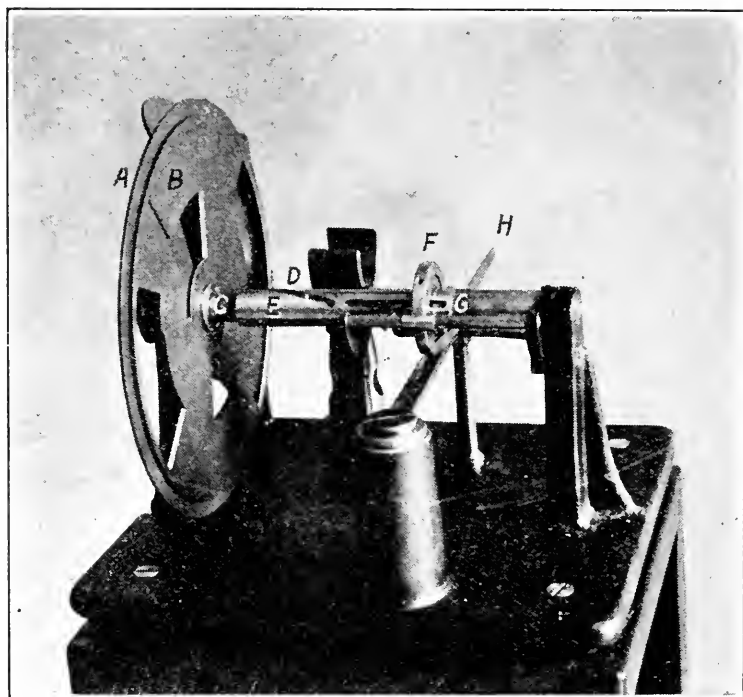
In addition, the sectors are so cut that two adjacent fields of view are presented. As the sectors are shifted, one field increases while the other decreases in brightness. In extreme positions, one field is black while the other is at maximum brightness—conditions are reversed as the sectors rotate, relatively through 90°. The shifting of the sectors is accomplished by well-known means.

The general construction of the instrument is shown in Fig. 1. Here, A and B are the two sectored discs; A is rigidly attached to the central shaft while B is attached to a sleeve C. This bears a pin which moves in the spiral slot D cut in a second sleeve E. Longitudinal motion of this sleeve is established by means of a clutch at F. Rotation of the sleeve E relative to that of the main shaft is prevented by a slot-and-pin arrangement at G. In order

to bring about a relative motion of the discs *A* and *B* it is only necessary to move the clutch lever *H* back and forth. This motion

Fig. 2.
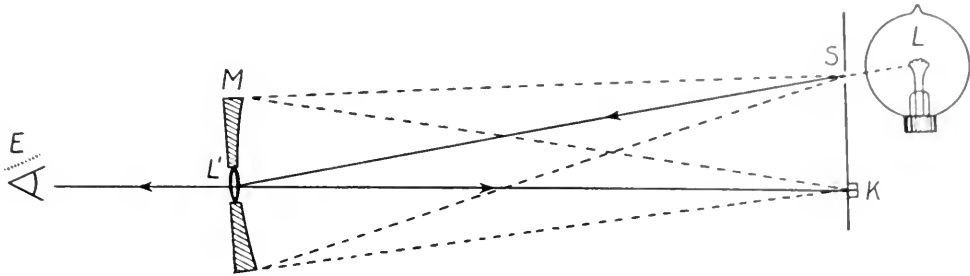
is quite free even when the speed of rotation exceeds 2500 R.P.M. and adjustments of the sector opening may be made by the most

Fig. 3.
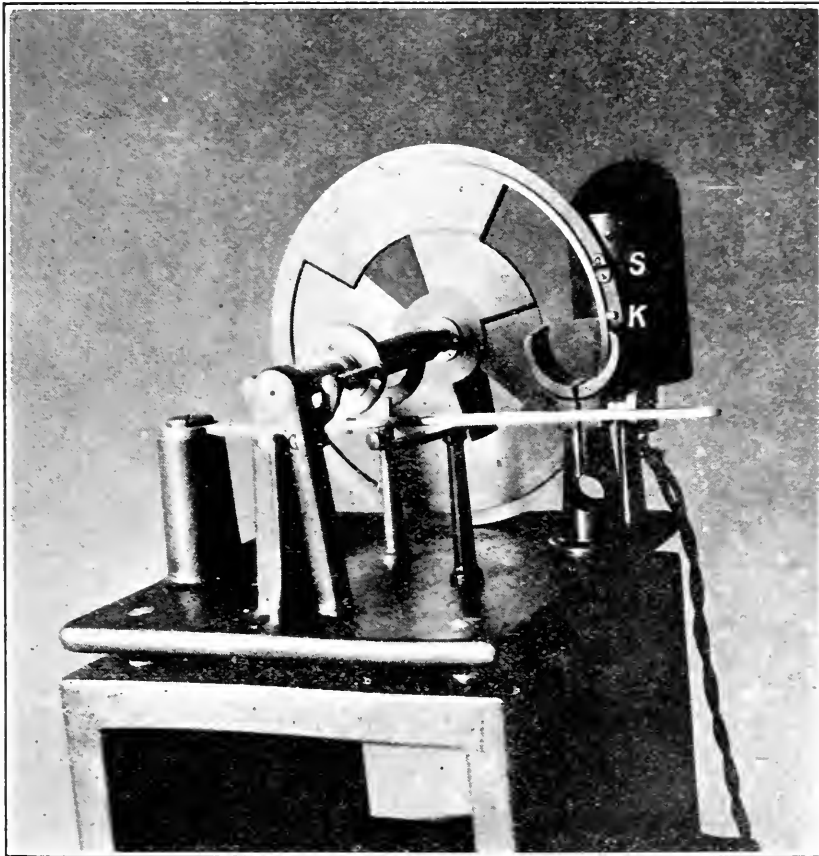
minute steps. Power is applied by means of a small motor (not shown) connected by a small belt to a pulley mounted on the end of the main shaft.

The simple stroboscopic device used to read off the relative positions of the two sectors is shown in Fig. 2. A narrow slit S is cut in the sector about three-quarters of an inch above the fiducial mark K. The light from a small tungsten lamp L passes through this slit and falls on the gold-coated concave mirror M, which projects a sharp image of the slit on K and

FIG. 4.
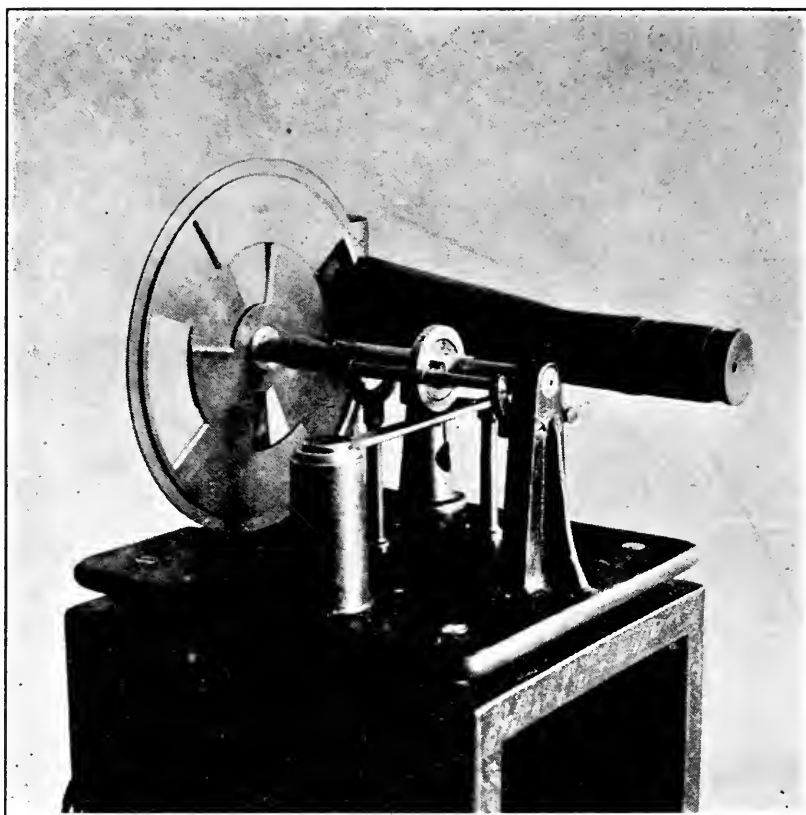
on the portion of the graduated scale immediately adjacent. The scale and marker K are polished and lacquered so as to reflect a large amount of the incident light back normally through the small lens L' mounted in a hole cut into the centre of the concave mirror. This lens is of such focal length as to present to the eye at E a magnified image of the scale. When the sector is set in motion, the scale is seen as clearly as though it were at rest—in fact, the most minute details such as scratches, etc., are depicted with astonishing clearness. For sharp delineation it is absolutely essential that the slit image be focussed sharply on the scale and

that the slit be as narrow as is consistent with obtaining light of sufficient intensity. The disposition of S and K are shown in Fig. 3 (the tube containing the mirror has been removed). If the sectors be rotated very slowly by hand, it is found that the slit image moves over the scale in a direction opposite to that of the scale. Since the relative velocity of image and scale is twice the peripheral velocity, it is observed that the stroboscopic image of the scale is contracted to one-half of its true width. In spite of this, it is easy to read the scale to 0.1 of a division.

It is, of course, clear that this stroboscopic device may be employed wherever the relative motion of rotating discs is to be measured. Experiments with motors, dynamos, phosphoroscopes, etc., offer opportunities for such applications. A consideration of the possibilities of various alternative schemes involving the use of periodic electrical contacts, sparks, telephones, etc., has convinced the writer that they are all inferior in accuracy to the direct reading of the scale engraved on the rotating discs themselves. The complete instrument with lamp-house and tube containing the mirror and lens system is shown in Fig. 4.

The application of this instrument to photometry, spectro-photometry and colorimetry are obvious. Altogether the instrument leaves but little to be desired.

The effects of "lost motion," "play," etc., are entirely eliminated, hence this instrument is justly termed "precision rotating sector."

In conclusion the writer wishes to thank Mr. J. P. Gaffney, University mechanician, for the great skill and the painstaking care which he has brought to bear on the construction of the instrument.

March, 1922.

Digestion of Raw Egg White.—MARY S. ROSE and GRACE MACLEOD, of Columbia University (*Jour. Biol. Chem.*, 1922, 1, 83-88), have studied the digestion of the protein of white of egg by man. The whites of from 10 to 12 eggs were consumed daily by each of ten subjects. The coefficient of digestion of cooked whites was 85.9 per cent., of unbeaten raw whites 76.6 per cent., of partly beaten and partly unbeaten raw whites 80.7 per cent., and of raw whites beaten light 83.8 per cent.; the average coefficient for raw whites of all types was 80.4 per cent. The conclusion is drawn that it is unnecessary to emphasize the difference between raw and cooked eggs, provided the raw eggs be beaten.   J. S. H.

Some Facts Bearing on the Structure of Atoms, Particularly of the Helium Atom. R. A. MILLIKAN. (*Phys. Rev.,* Dec., 1921.)—Professor Millikan has developed a wonderful method by which he can measure the electric charge on the fragment of an atom to the same degree of accuracy with which the census enumerates the number of people in the United States. When he applies this method to the atoms that have suffered bombardment by alpha rays coming from a bit of polonium he can tell exactly how many electrons have been knocked off, because each detached electron has carried away a definite and known quantity of negative electricity. When oxygen, nitrogen or carbon with their few electrons or iodine or mercury with their many electrons are subjected to assaults of the alpha particles, it is found that a single such particle practically never detaches more than one electron. "This, in itself, throws a certain light on atomic structure, for it shows conclusively that the electrons within an atom act quite independently of one another. They are certainly not in rings, of say four or eight or any other number which become unstable when one of their number is removed, or which can in general be shattered as a whole."

With helium it is different. The result is thus picturesquely phrased, "The alpha particle shooting at random through the helium atom at its maximum ionizing speed gets both electrons every sixth shot in which it gets anything." Such a fact does not determine the structure of the helium atom but it does make certain structures impossible. One such structure thus ruled out is the original Bohr arrangement according to which the helium atom has its two electrons at opposite ends of a diameter. Another is that suggested by Sommerfeld in which one electron rotates close to the nucleus while the other is in an orbit much farther away.

To kill the traditional two birds with one stone it is necessary that they be close together at the time of their demise. Similar reasoning leads to the conclusion that the two electrons which get knocked off once out of six must be close together in the atom a considerable part of the time. This is in consonance with the recent arrangements of Landé and of Bohr, according to which the electrons move in roughly equal orbits whose planes are inclined to each other. "Bohr may also find in it support for his recent contention that the outer shell of heavy atoms possesses few electrons instead of many as postulated in most of the discussions of the "static atom."

This article is from the Norman Bridge Laboratory of Physics, Pasadena, California, and may perhaps be regarded as the first fruits of Colonel Millikan's activities in his new surroundings.

G. F. S.

ON A METHOD OF CALCULATING FLUIDITY, SURFACE TENSION AND REACTION (EQUILIBRIUM) PRESSURE.*

BY

HENRY JERMAIN MAUDE CREIGHTON, D.Sc.

Department of Chemistry, Swarthmore College; Member of the Institute.

SOME years ago it was shown by Ramsay and Young [1] that for any pair of closely related substances—such as methyl acetate and ethyl acetate, or propyl propionate and propyl butyrate—the ratio of the absolute temperatures (T) corresponding to equal vapour pressures is constant, i.e., $T'_A / T'_B = T_A / T_B = $ a constant. For substances not closely related, it was found that the relation was less simple, but that it might be expressed by the equation $R' = R + c(T'_B - T_B)$, where R' is the ratio of the absolute temperatures of the two substances corresponding to any vapour pressure, the same for both; R is the ratio of the absolute temperatures at any other vapour pressure, again the same for both; and T'_B and T_B are the temperatures of one of the substances corresponding to the two vapour pressures. This relationship, which was tested by Ramsay and Young for 23 pairs of substances, has been found to hold up to the critical point. The method has been employed by Ramsay and Travers [2] to calculate the vapour pressures of the inert gases, argon, krypton and xenon, at various temperatures.

At the suggestion of Ramsay, Findlay [3] showed that a precisely similar equation to that of Ramsay and Young connects the absolute temperatures at which two substances have equal solubilities, and also the absolute temperatures at which two chemical equilibria have equal equilibrium constants.

The writer has found that the absolute temperatures at which two substances have the same value for certain other physical constants are related by an expression having the same form as the Ramsay and Young vapour pressure equation. In this paper the relations between the absolute temperature and fluidity, the

---

* Communicated by Professor Creighton.

[1] *Phil. Mag.* (5), **20**, 515 (1885); **21**, 33 (1886).

[2] *Phil. Trans.*, A., **197**, 47 (1901).

[3] *Proc. Roy. Soc.*, **69**, 471 (1902).

absolute temperature and surface tension, and the absolute temperature and reaction pressure (equilibrium pressure) are presented briefly.

The constant, c, in the equation $R' = R + c(T'_B - T_B)$, where R' and R are the ratios of the absolute temperatures of two substances, A and B, corresponding to two values of the physical constant, is determined as follows: Values of the ratio $R' = T'_A/T_B$, corresponding to a number of different values of

TABLE I.

Calculation of the Fluidity of Octane (A) from the Fluidity of Benzene (B).

$c = 0.000354.$

Fluidity ϕ	Observed Absolute Temperature†.		Ratio of Observed Temperatures T'_A/T'_B	Calculated Absolute Temperature T'_A	Calculated Fluidity of Octane ϕ calcd.	Difference ϕ calcd.—ϕ
	Octane[4] T'_A	Benzene[5] T'_B				
142.2	273.1	287.6	0.9497	273.4	142.6	+0.4
163.2	283.1	296.8	0.9540*	283.1	163.2	0.0
174.8	288.1	301.5	0.9557	288.1	174.8	0.0
185.9	293.1	306.1	0.9576	293.0	185.7	—0.2
197.4	298.1	310.8	0.9591	298.0	197.2	—0.2
209.9	303.1	315.5	0.9605	303.2	209.2	+0.2
233.7	313.1	324.9	0.9637	313.1	233.7	0.0
259.4	323.1	334.1	0.9673	322.8	258.8	—0.6
286.1	333.1	343.4	0.9701	333.2	286.3	+0.2

† In most of the examples which follow, the T'_A values are direct observations, while the T'_B values have been obtained by interpolation of experimental data.

the physical constant, are plotted against the absolute temperatures, T'_B, of one of the substances. A straight line is then drawn through the series of points obtained and "smoothed ratios" read off, corresponding to the temperatures T'_B. The values of the smoothed ratios are substituted in the equation $R' = R + c(T'_B - T_B)$ and the equation solved for c.

The success with which the fluidity (ϕ) of liquids can be calculated by means of the equation, $R' = R + c(T'_B - T_B)$, is illustrated by the examples given in Tables I and II. The former table gives in detail data obtained with octane (A) and benzene (B), while the latter, summarizing the results obtained, using propyl iodide (A) and perchlorethylene (B) and water (B) with each of several liquids (A), gives the " observed " and " calcu-

[4] Landolt-Börnstein, " Physikalisch-Chemische Tabellen," p. 78, Berlin, 1912.
[5] *Ibid.,* p. 80.

lated " absolute temperatures at which liquid A has a definite fluidity. In these and the following tables the asterisk denotes the temperature ratio R (or the absolute temperatures T_A and T_B, where $T_A / T_B = R$), from which the other temperature ratios (R') and the corresponding absolute temperatures (T_A') have been calculated.

It will be observed that the calculated and observed values in these tables agree very well, except in the case of mercury and water. This lack of agreement is partly due, at least, to the flatness of the fluidity-temperature curve of mercury, in consequence of which a small error in the fluidity gives a comparatively large error in the calculated value of the absolute temperature. Above $T_A' = 427.1°$, the difference between the observed and calculated absolute temperatures increases rapidly with rise in temperature. This may well be due to inaccuracies in the experimental data, since the values for the viscosity of mercury at high temperatures, as determined by Koch[6] and by Plüss,[7] differ considerably. It should be noted that much better agreement over a greater range has been obtained with fluidity values based on Koch's viscosity mesaurements than with those based on Plüss' determinations.

A number of other pairs of liquids that have been studied are given in Table III. With one exception, the agreement between the observed and calculated values of T_A', over the temperature interval studied, is as close as that given in Tables I and II. Indeed, in most cases, the agreement between the observed and calculated fluidity is closer than the values determined by different investigators. The pair of liquids, ethyl alcohol: water, does not follow the equation $R' = R + c(T_B' - T_B)$ even approximately. With these two liquids the temperature ratio T_A' / T_B', when plotted against T_B', instead of changing linearly, at first increases rapidly as T_B' increases, then more slowly and finally decreases. With aniline and water the agreement is good over the fluidity range given in the table, but the difference between the observed and calculated temperatures increases rapidly above the upper limit given for the fluidity. This is hardly surprising, as at higher temperatures values for the viscosity of aniline determined by different observers vary by 20 per cent. or more (*e.g.*, the values

[6] *Wied. Ann.*, **14**, 1 (1881).
[7] *Z. anorg. Chem.*, **93**, 1 (1915).

Table II.

Calculation of Absolute Temperatures Corresponding to Given Fluidities.

Methyl alcohol[8] (A) and Water[9] (B). c=0.000568				Acetic acid[10] (A) and Water[9] (B). c=0.00217				Mercury[11] (A) and Water[9] (B). c=0.0321				Phenol[12] (A) and Water[9] (B). c=0.00118				Propyl Iodide[13] (A) and Perchlorethylene[14] (B). c=0.000174			
T'_B obs.	ϕ	T'_A obs.	T'_A calcd.	T'_B obs.	ϕ	T'_A obs.	T'_B calcd.	T'_B obs.	ϕ	T'_A obs.	T'_A calcd.	T'_B obs.	ϕ	T'_A obs.	T'_A calcd.	T'_B obs.	ϕ	T'_A obs.	T'_A calcd.
319.0	170.5	293.1	293.7	284.7	80.4	293.1	293.0	274.9	59.2	273.1	273.4	276.9*	63.3	353.1*	353.1	288.7	100.6	273.1	272.7
323.0*	182.4	298.1*	298.1	291.0	94.2	303.1	303.4	276.1*	61.7	283.2*	283.2	289.1	89.9	373.1	372.8	300.2	120.9	283.1	283.0
327.6	195.1	303.1	302.9	293.8*	100.9	308.1*	308.1	277.3	64.1	293.1	295.1	296.0	106.3	383.1	384.1	311.6*	135.7	293.1*	293.1
332.5	209.9	308.1	308.3	296.7	108.2	313.1	313.0	280.3	70.7	323.1	325.3	304.9	129.8	398.1	398.9	323.0	151.2	303.1	303.2
336.6	223.7	313.1	313.0	299.5	115.6	318.1	317.8	285.2	81.5	372.1	375.8	318.7	168.9	423.1	422.1	334.4	167.1	313.1	313.2
341.0	238.0	318.1	317.9	302.6	123.3	323.1	323.1	287.2	85.4	397.1	396.3					346.0	184.0	323.1	323.4
345.6	253.7	323.1	323.1	305.6	131.5	328.1	328.3	289.8	91.6	427.1	424.7					357.2	201.2	333.1	333.2
350.0	269.5	328.1	328.1	308.5	139.8	333.1	333.4									368.3	219.3	343.1	342.8
354.4	286.5	333.1	333.2	311.6	147.9	338.1	338.8									383.1	243.0	355.7	355.6
																393.1	261.4	364.3	364.2

[8] Bingham, E. C., and J. L. Cadwell, Z. physik. Chem., 83, 649–50 (1913).

[9] Bingham, E. C., and G. F. White, ibid., 83, 646 (1913).

[10] Bingham, E. C., and G. F. White, loc. cit., 647.

[11] Koch, S., Wied. Ann., 14, 1 (1881).

[12] Bramley, A., J. Chem. Soc., 109, 10 (1915).

[13] Landolt-Börnstein, p. 79 (1912).

[14] Ibid., p. 78 (1912).

determined at $125°$ C. by Bramley [18] and by Kurnakow, Krotkow and Oksman [19]).

It was thought that the surface tension (γ) and absolute temperature of liquids might also be connected by an equation having the form, $R' = R + c(T'_B - T_B)$, where R' and R are the ratios of the absolute temperatures at which two liquids, A and B, have the same surface tensions. Unfortunately, it has only been possible to test the relation with a few pairs of liquids, owing to lack of experimental surface tension data covering a wide range. With the pairs of liquids studied, the agreement between the

TABLE III.

Liquids.		Fluidity Intervals.	c
A	B		
Pyridine [15]	Water [9]	75.6–259.7	0.00200
Acetic acid [16]	Propionic acid [17]	80.4–164.6	−0.000194
Propionic acid [17]	Water [9]	84.5–202.0	0.00218
Aniline [15]	Water [9]	64.7–157.0	0.00174
Quinoline [15]	Water [9]	59.8–182.8	0.00370
Dimethylaniline [15]	Water [9]	49.4–152.0	0.00267
Phenetole [15]	Water [9]	53.8–179.2	0.00184
Ethyl alcohol [16]	Water [9]	91.0–212.5	not constant

observed and calculated temperatures is good, as is illustrated by the data recorded in Table IV. In addition to those given in this table, the following pairs of liquids [21] have been studied: anisol and diethyl chloromaleate, diethyl phenylpropionate and thiophenol, diethylmaleate and toluene, and triphenylphosphine and triphenylstibine. It will be observed that not only does the relation hold for non-associated liquids (*e.g.*, bromtoluene and chlorbenzene), but that it also holds for an associated and a non-associated liquid (*e.g.*, acetic acid and toluene). In view of the good agreement obtained with the few examples studied, it is probable that, when additional surface tension data become available, the expression, $R' = R + c(T'_B - T_B)$, will be found to hold for other pairs of liquids.

[15] Bramley, A., *J. Chem. Soc.*, **109**, 10, 434 (1916).

[16] Bingham, E. C., and G. F. White, *loc. cit.*

[17] Dunstan, A. E., *J. Chem. Soc.*, **107**, 667 (1915).

[18] *Loc. cit.*

[19] *Bl. Acad. Sc. Pét.*, **9**, 45.

It has also been found that the equilibrium pressure (reaction or decomposition pressure) of various chemical reactions in solid-gas, or wholly gaseous, systems can be calculated at different temperatures by means of the expression, $R' = R + c(T'_B - T_B)$. Here R' is the ratio of the absolute temperatures at which two reactions, A and B, have the same equilibrium pressure, and R is the ratio of the absolute temperatures corresponding to another value of the equilibrium pressure, the same for both reactions. A number of types of reactions has been studied and, for pairs

TABLE IV.

Calculation of Absolute Temperatures Corresponding to Given Surface Tensions.

Acetic Acid[20] (A) and Tolune[21] (B); $c = 0.000270$				Bromtoluene[22] (A) and Chlorbenzene[21] c = zero			
T'_B obs.	γ	T'_A obs.	T'_A calcd.	T'_B obs.	γ	T'_A obs.	T'_A calcd.
299.0	26.87	303.1	302.6	287.7	32.992	283.1	282.9
308.6*	25.84	313.1*	313.1	298.1*	31.727	293.1*	293.1
317.9	24.82	323.1	323.3	308.3	30.441	303.1	303.1
327.0	23.80	333.1	333.4	318.3	29.521	313.1	313.0
335.7	22.80	343.1	343.1	328.5	28.079	323.1	323.0
344.8	21.79	353.1	353.2	338.3	26.925	333.1	332.6
353.9	20.81	363.1	363.5				
371.5	18.90	383.1	383.2				

of reactions of the same general type, the agreement between the observed and calculated results has been good in most cases. With pairs of reactions of different types, *e.g.,*

$$\text{(A)} \quad AgP_2 \rightleftarrows AgP + P, \text{ and}$$
$$\text{(B)} \quad 2CuSO_4 \rightleftarrows 2CuO + 2SO_3,$$
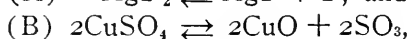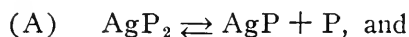
the expression does not hold for two out of the three pairs studied. This may, however, be due to inaccurate experimental data rather than to anomalous behavior of the reacting substances. The results obtained with three pairs of reactions are given in Table V, where it will be observed that the calculated absolute temperatures at which reaction A has definite equilibrium pressures agree closely with the temperatures determined by experiment. Other pairs of reactions that have been studied are recorded in Table VI.

---

[20] Bennett, J. M., *J. Chem. Soc.,* **107**, 351 (1915).
[21] Walden, P., and R. Swinne, *Z. physik. Chem.,* **79**, 708 (1912).
[22] Müller, A. H. R., *ibid.,* **86**, 177 (1914).

TABLE V.

Calculation of Absolute Temperatures Corresponding to Given Equilibrium Pressures.

(A) $2(Cr_2O_3.CuO) + 2CuO \rightleftarrows 2(Cr_2O_3.Cu_2O) + O_2$[23] (B) $2BaO_2 \rightleftarrows 2BaO + O_2$[24] $c = $ zero				(A) $Ca(OH)_2 \rightleftarrows CaO + H_2O$[25] (B) $Ba(OH)_2 \rightleftarrows BaO + H_2O$[26] $c = -0.000170$				(A) $NH_4Br \rightleftarrows NH_3 + HBr$[26] (B) $PH_4Cl \rightleftarrows PH_3 + HCl$[27] $c = $ zero			
T'_B obs.	Equilibrium Pressure mm.	T'_A obs.	T'_A calcd.	T'_B obs.	Equilibrium Pressure. mm.	T'_A obs.	T'_A calcd.	T'_B obs.	Equilibrium Pressure. mm.	T'_A obs.	T'_A calcd.
982.5*	176	1052*	1052	903	9.2	642	638	194	6	524	524
1020	322	1092	1092	943	17.4	662	660	203*	21	548*	548
1033	410	1106	1106	983*	31.5	681	681	209	43	569.5	565
1039	440	1113	1113	1022*	55	701*	701	213	63.5	582	575
1048	512	1121	1121	1062	92	721	721	228	195	616	616
1058	615	1133	1133	1102	149	741	741	233	289	629	629
				1143	234	761	761	236	363	637	637
				1183	355	780	779	241	532	652	651
				1224	526	800	802	244	645	659	659
				1271	760	820	818	247	813	668	667

[23] Wöhler L. and P., Z. physik. Chem., 62, 448 (1908).

[24] Chatelier, H. le. Compt. rend., 115, 655 (1892).

[25] Johnston, J., Z. physik. Chem., 62, 317 (1908).

[26] Johnston, J., ibid., 65, 38 (1909).

The data given in this paper show that, by means of an expression precisely similar to the Ramsay and Young vapour pressure equation, it is possible to calculate the fluidity (or viscosity) of liquids, the equilibrium pressure of chemical reactions and prob-

Table VI.

Reactions		Pressure Intervals mm.	Constant $c.$
1.	(A) $2BaO_2 \rightleftarrows 2BaO + O_2$ [24] .... (B) $2PbO_3Ca \rightleftarrows 2PbO_2Ca + O_2$ [24]	65–670	zero
2.	(A) $2(Cr_2O_3.CuO) + 2CuO \rightleftarrows 2(Cr_2O_3.Cu_2O) + O_2$ [23] . (B) $2PbO_3Ca \rightleftarrows 2PbO_2Ca + O_2$ [24]	176–795	zero
3.	(A) $2CuBr_2 \rightleftarrows 2CuBr + Br_2$ [28] .... (B) $2BaO_2 \rightleftarrows 2BaO + O_2$ [24]	22–597	not constant
4.	(A) $Sr(OH)_2 \rightleftarrows SrO + H_2O$ [25] .... (B) $Ba(OH)_2 \rightleftarrows BaO + H_2O$ [25]	9.2–760	0.000093
5.	(A) $Mg(OH)_2 \rightleftarrows MgO + H_2O$ [25] .... (B) $Ba(OH)_2 \rightleftarrows BaO + H_2O$ [25]	9.2–760	–0.000062
6.	(A) $Fe_2(SO_4)_3 \rightleftarrows Fe_2O_3 + 3SO_3$ [$SO_2.O_2$] [29] .... (B) $Al_2(SO_4)_3 \rightleftarrows Al_2O_3 + 3SO_3$ [$SO_2.O_2$] [29]	33–560	zero
7.	(A) $NH_4Br \rightleftarrows NH_3 + HBr$ [30] .... (B) $NH_4I \rightleftarrows NH_3 + HI$ [30]	6–532	zero
8.	(A) $ZnSO_4 \rightleftarrows ZnO + SO_3$ [$SO_2.O_2$] [29] .... (B) $2AuCl \rightleftarrows 2Au + Cl_2$ [31]	24–189	–0.00099
9.	(A) $AgP_2 \rightleftarrows AgP + P$ [32] .... (B) $2CuSO_4 \rightleftarrows 2CuO + 2SO_3$ [$SO_2.O_2$] [29]	59–214	not constant

ably the surface tension of liquids. The agreement between the calculated and observed data presented in the preceding tables indicates that values obtained by this method represent a close approximation of the truth. The utility of the expression $R' = R + c(T'_B - T_B)$ is evident, for if values of one of the physical constants are known over a wide range of temperatures for one substance (B), and if the value of the constant is determined at a few temperatures for a second substance (A), then its value for the

[27] Tammann, G., "Krystallisieren und Schmelzen," 1903, p. 289.
[28] Jackson, C. G., *J. Chem. Soc.*, **99**, 1066 (1911).
[29] Wöhler, L., W. Püddemann and P. Wöhler, Ber., **41**, 703 (1908).
[30] Johnston, J., *Z. physik. Chem.*, **65**, 38 (1909).
[31] Meyer, F., *Compt. rend.*, **133**, 817 (1901).
[32] Granger, *Ann. chim. phys.*, (7), **14**, 5 (1901).

latter can be calculated over a range corresponding to the range of the known values for the first substance (B). To do this, the values of the ratio $T'_A/T'_B = R$ are plotted against the absolute temperatures T'_B and a straight line drawn through the points. By multiplying a particular temperature, T'_B, by the corresponding temperature ratio (read off from the curve), the absolute temperature, T'_A, is obtained at which the value of the physical constant of the substance A is equal to that of the substance B at the absolute temperature T'_B. If the line does not run through the points (i.e., if c is not constant), it is probable that the experimental data are not accurate, or that one of the substances behaves abnormally.

SWARTHMORE, PA.,
  March 16, 1922.

The Atomic Process in Ferromagnetic Induction. SIR J. A. EWING. (*Proc. Royal Society*, A 706.)—In 1890 the author brought to attention a model which embodied his conception of ferromagnetic induction. In one plane it consisted of a group of similar, pivoted magnets. When no external magnetic force acts, these form configurations under the influence of their mutual attractions and repulsions, and when an external force is brought into action, as by the insertion of the group of magnets into a magnetizing coil, it is their mutual forces which must be overcome before the magnets can turn into the direction of the applied magnetizing force. Such a model simulated many of the phenomena manifested when a piece of iron is magnetized and, indeed, with striking completeness. Professor Ewing, however, finds that there is a great discrepancy between the magnetizing force really needed to make iron pass from the reversible to the irreversible stage and that which would be needed to accomplish the same change were the elementary magnets subject alone to their mutual attractions. He finds it necessary to place near each pivoted magnet two pairs of permanent magnets. Each pair has poles arranged thus, N S–S N and the axes of both magnets lie in the same line, but the directions of these lines are different for the two pairs. The pivoted magnet can turn within the magnets forming a pair without touching either. There is assumed to be a slight dissymmetry in the strength or in the position of the two magnets in the same line.

When it comes to seeking in the actual atom something akin to this highly artificial arrangement, it is suggested that a pair of electrons on opposite sides of the nucleus of the atom may correspond to the pivoted magnet, while groups of electrons farther away from the centre may play the rôle of the fixed magnets. The new type of model is far removed from the simplicity of its predecessors of 1890,

which did so much to clarify magnetic conceptions when hysteresis was a new thing. Magnetism is, however, in itself no simple matter and investigation seems to increase the number of problems awaiting solution rather than to furnish a clue to already existing difficulties. It would therefore appear that a complex model is needed to represent complex effects and surely no one is better fitted to make fruitful suggestions in this field than one who has already succeeded eminently.

<div style="text-align:right">G. F. S.</div>

A New Hydrogen Process.—Much attention has been paid of late years to methods of obtaining hydrogen, principally on account of its use in the treatment of fats and for the inflating of dirigibles. It has also some applications as a reducing agent and as fuel. The use of ferrosilicon in solution of sodium hydroxide is one of more recent methods, which is described in a paper by E. R. Weaver, presented at the forty-first meeting of the American Electrochemical Society in April last. Although more expensive than other processes, it is suitable for military use on account of the small cost of the plant and the simplicity of operation. The reaction is between the silicon and the alkali, and the principal equation is

$$2NaHO + Si + H_2O = Na_2SiO_3 + 2H_2.$$
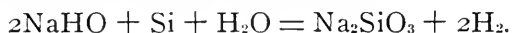
This represents the change at the beginning of the operation, but secondary reactions occur by the hydrolysis of the sodium silicate. The temperature must be controlled during the process. The facts that none of the materials used are combustible, that they do not give off any gas until mixed, and are easily transportable, are especially advantageous in naval operations. The gas produced is of high purity, traces of phosphine and acetylene being the principal impurities, although hydrocarbons and even arsine may occur. The disposal of the exhausted liquor is, however, a serious matter, as it is too alkaline to be thrown into a running stream.

<div style="text-align:right">H. L.</div>

Latent Heat of Fusion. MRS. K. STRATTON and J. R. PARTINGTON. (*Phil. Mag.*, March, 1922.)—The method seems to be new. A known mass of solid is maintained at its melting point by being surrounded by a mixture of the solid and liquid phases of the same substance. Heat is then imparted to the mass by sending an electric current through a resistance coil. This is continued until all the solid has just turned into liquid. Of course adequate stirring is provided. From the energy added and the mass of the solid it is easy to calculate the latent heat of fusion. In the case of benzo-phenone three separate experiments gave these values for the specific heat, 21.64, 21.79 and 21.58 calories per gram. An attempt was made to get the latent heat of rhombic sulphur, but it failed owing to the transformation into the monoclinic variety that occurred during the course of the experiment.

<div style="text-align:right">G. F. S.</div>

COMMUTATION IN CONTINUOUS CURRENT DYNAMOS.*

BY

ALFRED STILL.

Professor of Electrical Design, Purdue University.

THIS article is an attempt to explain in the simplest possible manner the theory of commutation by emphasizing the physical aspects of the problem and avoiding mathematical expressions and formulas of which the meaning and derivation cannot be easily understood. With this end in view, considerations of a mechanical nature, such as vibration, uneven or oily commutator surface, insufficient or excessive brush pressure, etc., will not be considered. Ideal or " straight-line " commutation will be assumed, and the conditions necessary to produce this—generally desirable—result investigated, in order that a multitude of more or less arbitrary assumptions may not obscure the problem in its early stages. By working from the simplest possible case to the more complex it is thought that the object in view—a physical conception of commutation phenomena leading to practical ends—will best be served, and influencing factors of relatively small practical importance will be either disregarded or but briefly referred to.

The theoretical investigation of commutation phenomena is admittedly difficult, partly because it is impossible to take account of the many causes which may lead to sparking at the brushes, but also because there can be no general solution of the problem applicable to the many different designs and windings of continuous current armatures. It is for these reasons that the writer does not hesitate to adopt the method proposed by Mr. Lamme,[1] who was the first to put the theory of commutation in a new light, thus clearing away much of the vagueness, if not inaccuracy, which accompanied the earlier methods of studying commutation phenomena.

---

* Communicated by the Author.

[1] B. G. Lamme, " A Theory of Commutation and its Application to Interpole Machines," *Trans. A.I.E.E.,* vol. xxx, pp. 2359–2404.

A continuous current dynamo is provided with a commutator in order that unidirectional currents may be drawn from armature windings in which the current actually alternates in direction as the conductors pass successively under poles of opposite kind. As each coil in turn passes through the zone of commutation, it is short-circuited by the brush, and during the short lapse of time between the closing and opening of this short-circuit the current in the coil must change from a steady value of $+I_c$ to a steady value of $-I_c$.

Let $W =$ surface width of brush (brush arc) in centimetres.
$M =$ thickness of insulating mica in centimetres.
$V_c =$ surface velocity of commutator in centimetres per second.

The time of commutation in seconds may then be written,

$$t_c = \frac{W - M}{V_c}$$

Since M is usually small with reference to W, it is generally permissible to express the time of commutation as $t_c = \dfrac{W}{V_c}$; that is to say, the time taken by any point on the commutator surface to pass under the brush is approximately the same as the duration of the short-circuit. It is during this time, t_c, that the current in the commutated coil must pass through zero value in changing from the full armature current of $+I_c$ to the full armature current of $-I_c$. If R is the resistance of the short-circuited coil, and if any possible disturbing effect of brush contact resistance be neglected, it is evident that the e.m.f. in the coil should be $e = I_c \times R$ at the commencement of commutation. At the instant of time when the current is changing its direction (i.e., when no current is flowing in the coil) the e.m.f. is $e = O \times R = O$. At the end of the time t_c, when the coil is just about to be thrown in series with the other coils of the armature winding carrying a current $-I_c$ amp., the e.m.f. in the coil should be $e = -I_c R$. It is when the e.m.f. in the coil has some value other than this ideal value that sparking is liable to occur.

Theory of Commutation.—Consider a closed coil of wire of T_c turns moving in a magnetic field. At the instant of time $i = O$ the total flux of induction passing through the coil is $+ \phi_0$ maxwells, and at the instant of time $t = t_c$ sec. the total flux

through the coil is $+\phi_t$ maxwells. Then, on the assumption that the flux links equally with every turn in the coil, the average

FIG. 1.
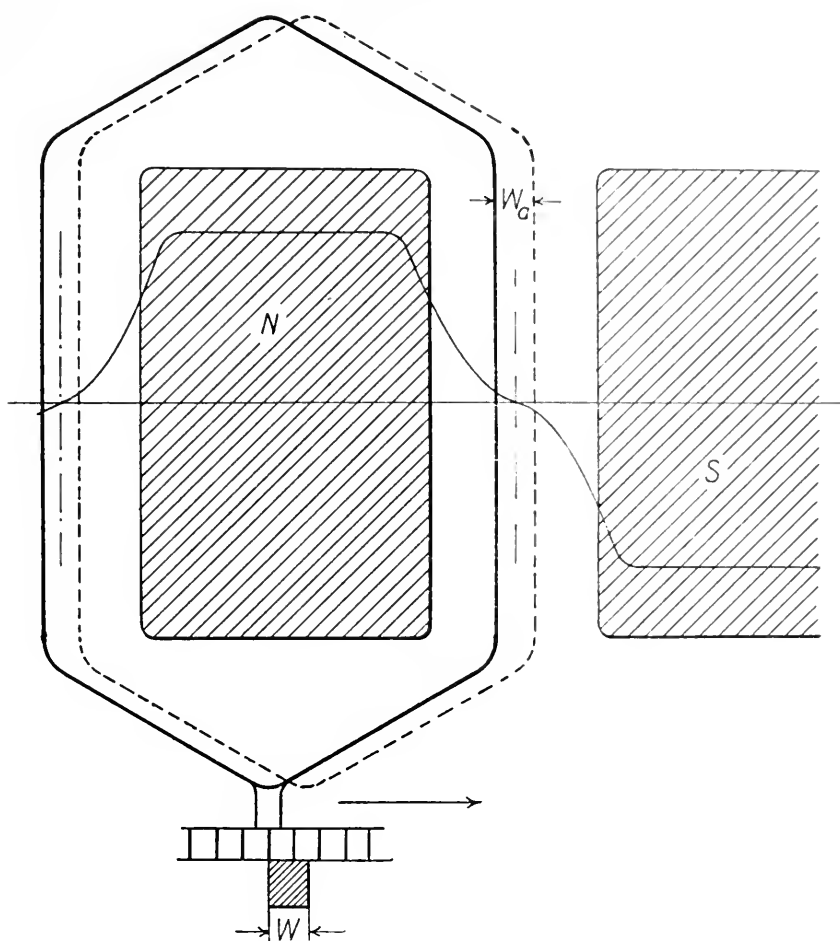
value of the e.m.f. developed in the coil during the interval of time t_c is

$$E_m = \frac{(\phi_t - \phi_o)\, T_c}{t_c \times 10^8}\ \text{volts.} \tag{1}$$

If R is the ohmic resistance of the coil and e is any instantaneous value of the e.m.f. produced by the cutting of the actual magnetic field in the neighborhood of the coil, the instantaneous value of the current in the coil is $i = \dfrac{e}{R}$ because e is the only e.m.f. in the circuit tending to set up a current. The usual conception of a distinct flux due to the current i producing a certain flux linkage known as the self-inductance of the circuit

is avoided; but its equivalent has not been overlooked seeing that the magneto-motive force due to the current in the coil is a factor in the production of the flux actually linked with this current at the instant of time considered.

Following the lead of Mr. Lamme, the wires in the coil undergoing commutation will be thought of as cutting through a total

FIG. 2.
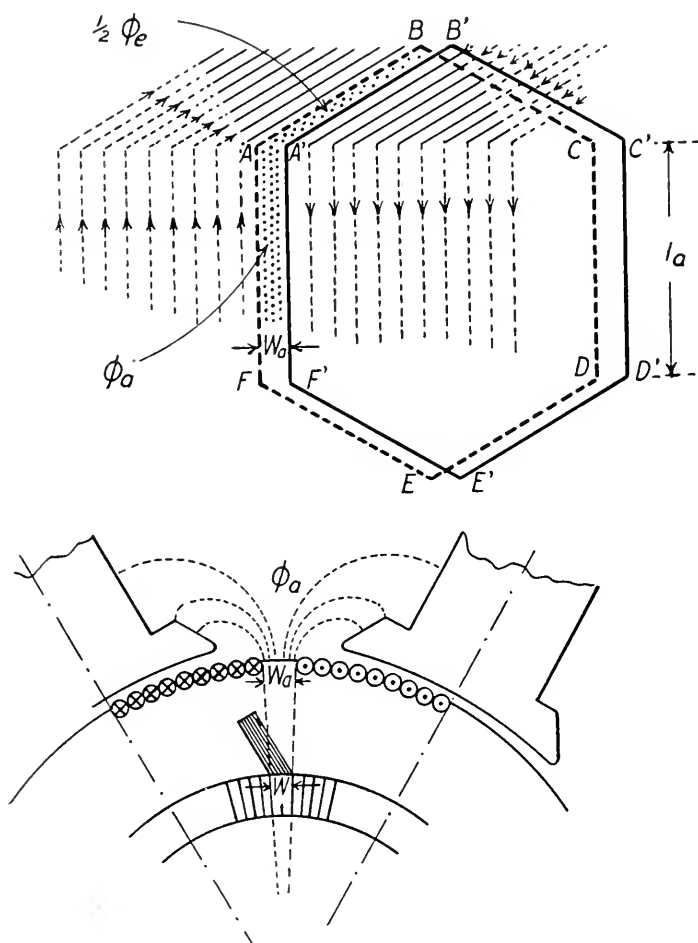
flux of induction, expressed in magnetic lines or maxwells, this flux being the resultant of the magnetizing forces of field coils and armature windings combined.

If a full-pitch armature coil is short-circuited by the brush while half-way between the N and S pole tips—that is to say, while the coil sides are in the geometric neutral zone—the magnetic fluxes due to the main poles are cancelled and their effect need not be considered. It is then only the flux set up by the armature winding itself (considered separately from the field

fluxes) which is effective in producing an e.m.f. in the coil undergoing commutation. The fact that the flux from the field poles which passes through the short-circuited coil is the same at the end as at the beginning of commutation—when this occurs in the " geometric " neutral zone—is clearly shown in Fig. 1. Here W_a is the distance of travel of the armature conductors

FIG. 3.
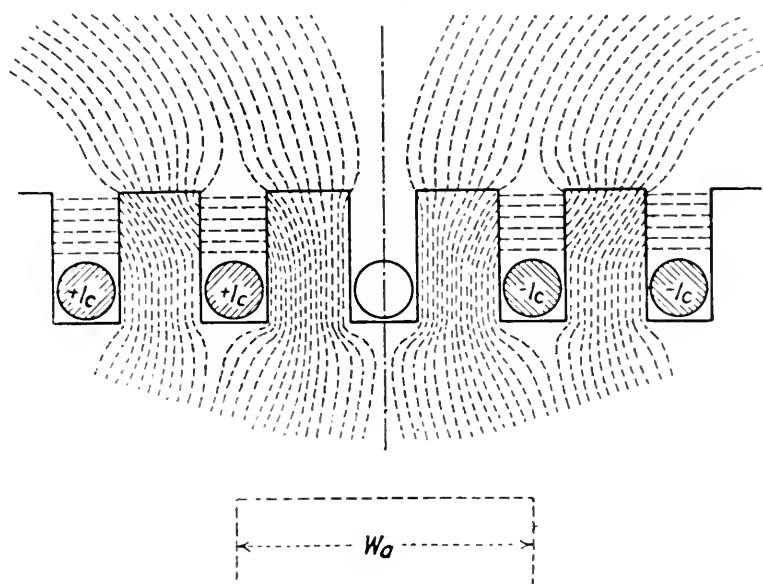
Flux distribution in commutation zone.

during the time of short circuit : it may be defined as the brush width referred to the armature periphery. Thus $W_a = W \cdot \dfrac{D}{D_c}$ where W is the brush width (or brush arc), D is the diameter of the armature and D_c is the diameter of the commutator. The curve shows the distribution of flux density over the armature surface, being positive, or (say) from the N pole when measured above the datum line, and negative, or of opposite polarity, when measured below the datum line. It is obvious that with all poles of the same size and shape, excited with the same number of ampere turns, the flux density will be zero on a line exactly half-way between the poles; and since the resultant flux through a coil of width equal to pole pitch is exactly the same for both positions of the coil shown in the figure, it follows that the *mean* voltage developed in the coil while moving through the distance W_a is zero. If this distribution of flux in the com-

mutating zone were not disturbed by the currents in the armature conductors, commutation would offer no serious difficulties even under heavy loads.

Magnetic Flux Due to Armature Currents.—The brushes are still supposed to be in such a position that the coil sides are at a point midway between poles when the mica which separates the two ends of the coil is under the centre of the brush. When considering the changes in flux density brought about by the currents in the armature windings, it is permissible and convenient to think of the magnetic fluxes in the zone of commutation, which are due to the armature current, as distinct from other fluxes, and also as *fixed in space* and therefore *cut* by the armature conductors as they move across it. For those who may experience difficulty in conceiving of a *stationary* flux[2] due to currents in *moving* armature conductors which are themselves cutting this same flux, it may be more convenient to revert to formula (1) and consider merely what is the difference $(\phi_t - \phi_o)$ between the amount of flux which links with the coil at the end of the period of short circuit and that which linked with the coil at the beginning of the period of short circuit. If this difference is zero, commutation will have taken place in a neutral field which is the ideal condition for sparkless commutation.

In Fig. 2, the dots between the two extreme positions of the coil undergoing commutation indicate flux lines, all of the same polarity, which are due to the armature currents only. The fact that there will be some flux, ϕ_a, due to the ampere turns on the armature in the zone of width W_a and length l_a (*i.e.*, the gross length of the armature core) is generally understood, but that the same is true of the end connections is not always so clearly realized. It will, however, be evident from an inspection of Fig. 2 that flux of the same kind as that in the space $FAA'F'$ will be found in the space $ABB'A'$, although it may be of lower density. This flux is due to the conductors running parallel to $A\ B$ carrying currents which are opposite in direction on the two sides of the space considered. What has been said of the space $ABB'A'$

---

[2] It is true that there are certain flux oscillations and pulsations which depend upon the slot pitch, the number of coil sides in a slot, and the relation of brush width to width of commutator bar, but these produce only minor variations in the e.m.f. induced in the coil during commutation, and since these can usually be taken care of by the surface resistance of carbon brushes, their existence will be ignored for the present.

applies equally to the flux cut by portion FE of the end connec-tions, and if the coil-side $EFAB$ cuts through a positive flux $(\phi_a + \phi_e)$ it will readily be seen that coil-side $BCDE$ cuts through an equal amount of negative flux, so that the difference in the amount of flux enclosed by the coil at the end and beginning of commutation (the quantity $\phi_t - \phi_0$ of formula (1)) is $2(\phi_a + \phi_e)$. This difference of flux will always occur unless the brushes are shifted so as to bring the short-circuited conductors into a field

FIG. 4.
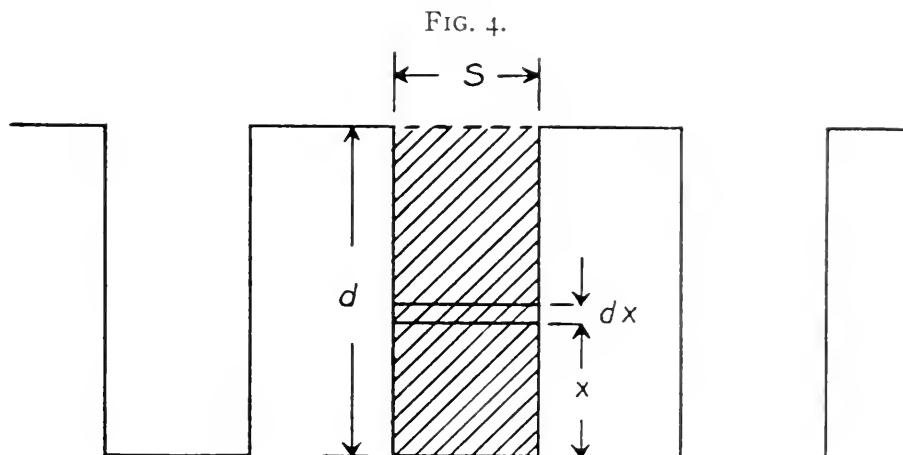
from the main poles sufficient to annul it, or unless commutating poles are provided.

Whether in a dynamo or motor, the flux due to the armature currents is always such as to set up e.m.f.s in the short-circuited coil tending to oppose reversal of the current. It is for this reason that the important element in the problem of commutation, from whatever point of view it is approached, is, and always will be, the correct determination of the field in which the short-circuited coil is moving, whether this conception of the magnetic condition is buried in the symbols L and M, and referred to as inductance, expressed in henrys, or considered merely as any other magnetic field; which is the method followed in this article. Although the end flux (the quantity ϕ_e) is not easily calculated, it is rarely of negligible amount and should not be left out of con-sideration. It is true that we do not concern ourselves with the end fluxes when calculating the useful voltage developed in the active coils; but, apart from the fact that in this connection the amount of the end flux is relatively small, it is not difficult to see that the e.m.f.s generated in the end connections as they cut

through the end fluxes due to the armature currents balance or counteract each other and have no effect upon the terminal voltage. The conception of the end connections cutting through the flux due to the armature as a whole, as indicated in Fig. 2, seems more natural, and is more helpful to the understanding of commutation phenomena, than what might be termed the academic method, in which more or less reasonable assumptions are made in respect to self and mutual inductances; but it is not

FIG. 5.
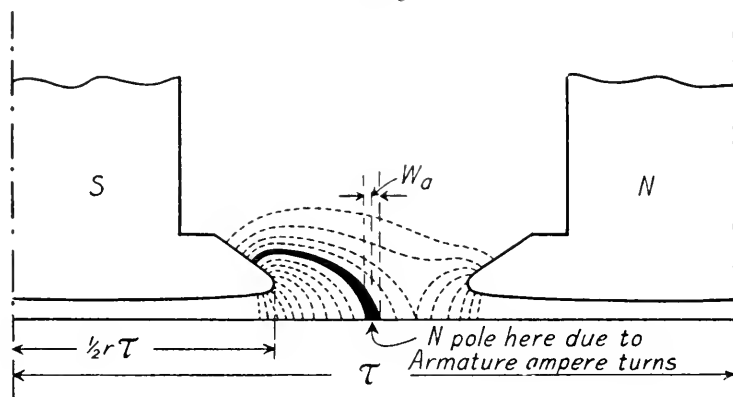
suggested that one method is necessarily superior to the other so far as practical results are concerned. While moving from the position at the commencement of commutation where the current is $+I_c$ to the position at the end of commutation where the current is $-I_c$, the short-circuited coil has cut through the flux of self and mutual induction—through the whole of it, not merely through certain components of the total flux in the particular region considered. This is well expressed by Mr. Menges when he says [3] : " . . . Self-induction is in no way distinguishable from other coexistent electromagnetic induction. Therefore, when the real magnetic flux resulting from all causes, and its changes relative to a given circuit, are taken into account, the self-induction is already included, and it would be erroneous to add an e.m.f. of self-induction."

Effect of Slot Flux.—Practically all modern dynamos and motors have slotted armatures and since the effect of the slot leakage flux on commutation has not yet been discussed, it will be necessary to consider it before proceeding farther. In Fig. 3

[3] C. L. R. E. Menges in the *Electrician,* Feb. 28, 1913.

an attempt has been made to represent, by the usual convention of magnetic lines, the flux due to the armature current alone, which enters or leaves the armature periphery in the interpolar space when the field magnets are not excited. The position chosen for the brushes is the geometric neutral (*i.e.*, the point midway between two poles) and the magnetic lines leaving the teeth will cross the air spaces between armature surface and field poles and so close the magnetic circuit. The brush is supposed to cover

FIG. 6.
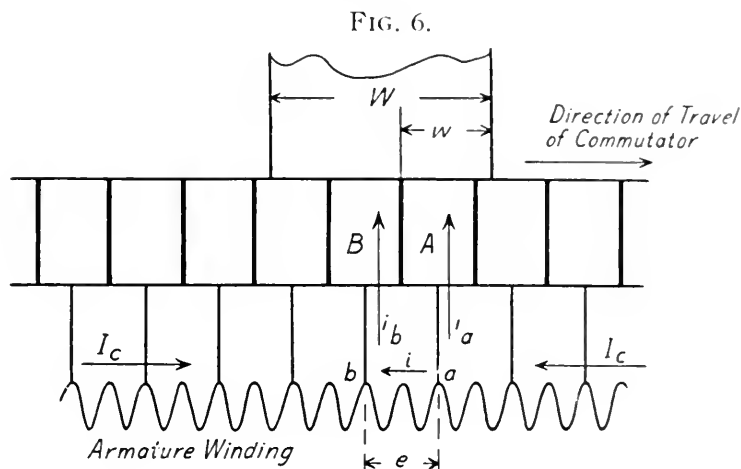
an angle equal to twice the slot pitch. The current in the conductor just before the short-circuit occurs is $+I_c$, the current in the conductor occupying the slot corresponding to a position under the centre of the brush is zero, and the current in the conductor just passing out from the short circuit is $-I_c$. The armature is supposed to be rotating, and it will be seen that the conductors in which the current is being commutated are cutting the flux set up by the armature as a whole. It is important to note that the flux cut by a conductor while travelling between the two extreme positions during which the short circuit obtains is not limited to the flux passing into the air gaps from the tops of the teeth included between these positions of the conductor, but includes also the flux due to the currents in the short-circuited conductors, which crosses the slot above the conductor [4] and leaves the armature surface by teeth which are not included between the two extreme positions of the short-circuited coil. This picture of the

---

[4] For the sake of simplicity, a single conductor is shown at the bottom of each slot and the whole of the slot flux is supposed to link with it. The calculation of the "equivalent" slot flux will follow.

conductor cutting the field set up by the armature currents is especially useful when calculations are made, as will frequently be found useful, by considering the separate component fluxes due to distinct causes, all combining to produce the actual or resultant flux. It is not difficult to see that the flux shown in Fig. 3 is never such as to generate an e.m.f. tending to reverse the current in the short-circuited conductor.

Calculation of Slot Flux.—Instead of all the slot flux passing

FIG. 7.
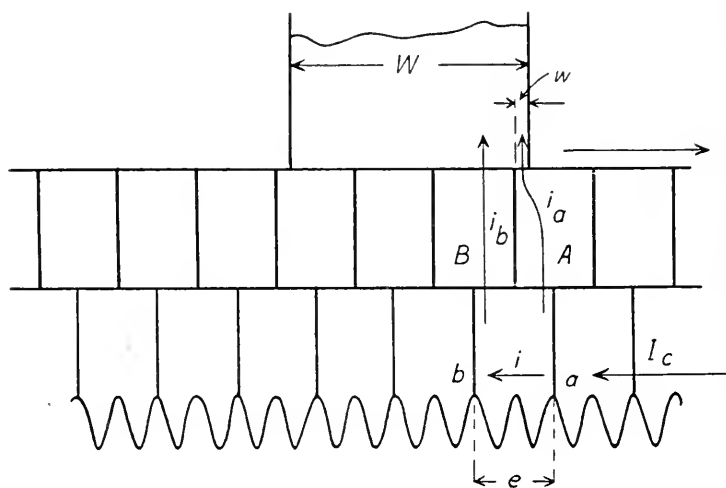
above the conductors to which it owes its existence, as shown in Fig. 3, much of this flux will actually pass through the copper in the slot. In order to simplify the calculations and yet obtain formulas of sufficient accuracy for the purpose of the designer, the whole of the slot—including the space usually occupied by the wedge—will be supposed occupied by the coils, the slot dimensions (in centimetres) being as indicated in Fig. 4. It will be convenient to assume the same number of commutator bars as there are slots, and each slot to be filled with $2T$ conductors, each carrying I_c amp. (This follows from the assumption of a full-pitch winding.) Thus no account will be taken of the fact that a small space occurs between upper and lower coils where the slot flux will not pass through the material of the conductors. The lines of the slot flux will be supposed to take the shortest path from tooth to tooth; the small amount of flux that may follow a curved path from corner to corner of tooth at the top of the slot will be neglected. Refinements of this nature may be introduced, if desired, when solving the problem for a concrete case.

If the usual assumption is made that the reluctance of the iron in the path of the magnetic lines is negligible in comparison with the slot reluctance, the small portion of slot flux in the space dx (Fig. 4), considered one cm. long axially (*i.e.*, in a direction perpendicular to the plane of the paper) is

$$d\phi = \text{m. m. f.} \times dP$$

where dP is the permeance of the air path. Thus

$$d\phi = 0.4\,\pi\,(2\,T\,Ic)\frac{x}{d} \times \frac{dx}{s}$$

and the total slot flux *per centimetre of axial length* in the zone of commutation—being *twice* the flux per slot (see Fig. 3)—is

$$\phi_s = \frac{0.8\,\pi\,(2\,T\,Ic)}{ds} \int_0^d x\,dx$$

$$= \frac{0.8\,\pi\,d\,T\,Ic}{s} \tag{2}$$

Since this flux is not cut equally by all the conductors in the slot the volts generated in the short-circuited coil by the cutting of this leakage flux will depend upon what may be termed the *equivalent* slot flux. This may be defined as the amount of flux which, if cut by all the conductors in the slot, would generate in the coil the same e.m.f. as results from the cutting of the actual slot flux. Thus, the element of flux in the space of depth dx (Fig. 4) links only with $2\,T\left(\frac{x}{d}\right)$ conductors,[5] and the equivalent amount of flux which, if cut by all the conductors in the slot, would generate the same e.m.f. is therefore

$$d\phi_{(\text{equiv.})} = d\phi \times \frac{x}{d}$$

whence

$$\phi_{(\text{equiv.})} = \frac{0\cdot8\,\pi\,T\,Ic}{d^2\,s} \int_0^d x^2\,dx$$

$$= \frac{0\cdot8\,\pi\,d}{3\,s}\,T\,Ic \quad \text{maxwells per slot.}$$

The total slot flux cut by each coil side during commutation,

---

[5] These calculations are based on the assumption of a large number of turns in the armature coils. When the winding consists of only one or two conductors of large cross-section in each slot, the current distribution will not be quite uniform as here assumed.

being twice the flux per slot, as previously explained, the final expression for the equivalent slot flux per centimetre axial length of the armature when the path of the flux lines is up through the root of the tooth and outward across the slot through the copper of the conductors, is

$$\phi_{es.} = \frac{1 \cdot 6 \pi d}{3 s} T I_c \quad \text{maxwells.} \tag{3}$$

Formulas for Calculating Armature Flux and End Flux in the Zone of Commutation.—It is not possible to develop an accurate

Fig. 8.

Current Density — Amperes per Sq. In.
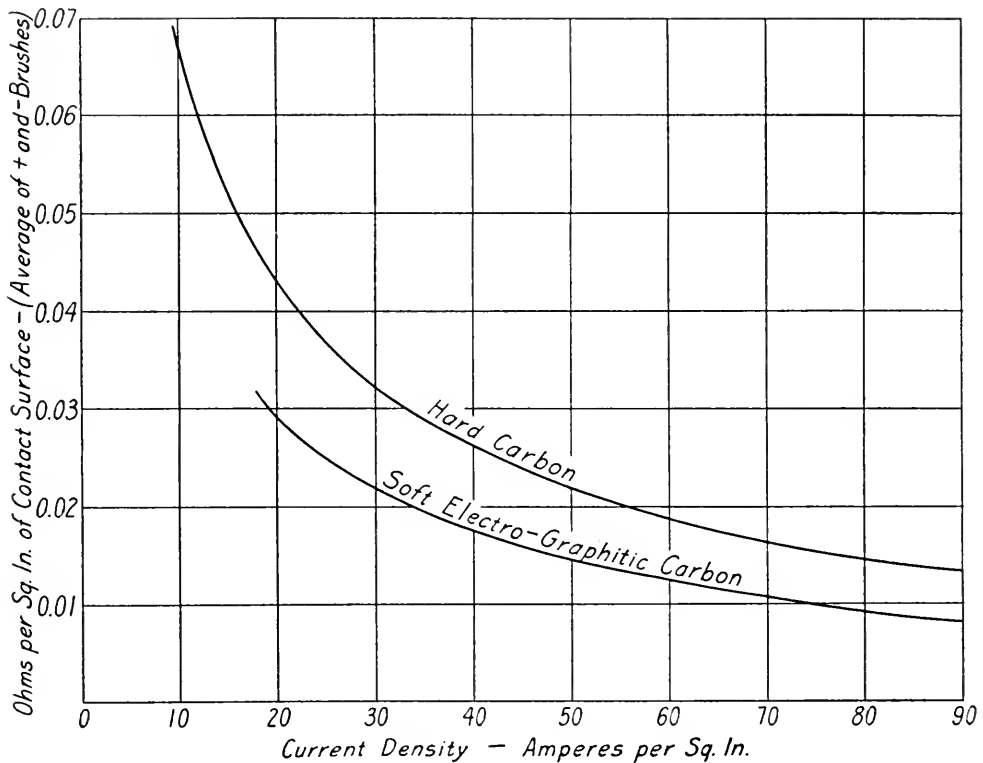
general formula for the amount of the " armature flux " cut by the short-circuited coils. By " armature flux " is meant the flux due to the ampere turns on the armature which passes between the field poles and the tops of the armature teeth comprised in the zone of commutation (the space IV_a of Figs. 1 and 2). The path taken by the flux lines is not easily predetermined, and it will depend not only upon the slope and distance apart of the pole shoes, but also upon the position of the brushes. A formula of sufficient accuracy for practical purposes may be developed as follows:

The flux entering the zone of commutation of width W_a exactly half-way between the two pole tips is due to the armature m.m.f. only, because the m.m.f.s of the two field poles neutralize at this point. When the field poles are excited, the flux path will be between the armature core and the field pole of opposite kind, generally as indicated in Fig. 5. The length of this flux path, whether it terminates at the pole shoe or higher up on the side of the pole core, depends mainly upon the distance between the pole tips, or $(1 - r)\tau$ where $\tau =$ pole pitch and r is the ratio $\dfrac{\text{pole arc}}{\text{pole pitch}}$.

It can be shown that, when r has a value between 0.6 and 0.8 and the number of poles is not less than six, the reluctance of this flux path per square centimetre of armature surface is approximately $\dfrac{\pi}{4}\tau(1 - r)$ where τ is in centimetres. The density of the flux entering the armature core at a point half-way between the poles when the position of the brushes is such that commutation takes place with the coils in the geometric neutral zone, is

$$B_a = 0.4\,\pi\left(\frac{ZI_c}{2p}\right)\frac{4}{\pi\tau(1-r)}$$

where $Z =$ the total number of armature conductors carrying a current I_c, and $p =$ number of poles; the quantity in brackets being the armature ampere turns per pole.

If D is the diameter of the armature core in inches, we have $\tau = \dfrac{\pi D \times 2.54}{p}$ which leads to the simplified expression

$$B_a = \frac{ZI_c}{10(1-r)D}\quad\text{gausses.}\qquad(4)$$

A more correct formula, which takes account of the increased length of flux path with the curvature as the number of poles is reduced, is

$$B_a = \frac{ZI_c}{7\left(1+\dfrac{2}{p}\right)(1-r)\,D}\quad\text{gausses.}\qquad(5)$$

Formulas for calculating the flux cut by the end connections of the armature winding are not applicable to all sizes of machines and types of winding, and they should be considered as approxi-

mations only unless they contain empirical constants which have proved to be reasonably accurate for the particular type of armature to which they apply. By making certain assumptions the writer has developed elsewhere [6] a formula which he has found to be sufficiently accurate for the purposes of the designer. This gives the flux cut by the two ends of one coil side (*i.e.*, half the end connections of a complete armature coil) as

$$\phi_e = 0.4 \sqrt{2}\ k\,W_a\,n\,TI_c \left[\log_\epsilon \frac{2\,\tau}{W_a} - 1 \right]$$

where n = number of slots in the space of one pole pitch, and k has a value between 1.5 and 3, the highest value being used when the overhanging ends of the armature coils are secured against iron supporting rings by steel wire bands. The dimensions τ and W_a must be in centimetres.

A close approximation to the quantity in brackets is $0.6 \sqrt{\dfrac{\tau}{W_a}}$ and by assuming the total axial projection of the armature coils outside of the slots to be 0.44τ, the formula becomes

$$\phi_e = 0.3\ k\,W_a\,n\,TI_c \sqrt{\frac{\tau}{W_a}} \quad \text{maxwells.} \tag{6}$$

With the aid of these formulas it is possible to determine approximately the average total e.m.f. developed in the coil during the time of commutation by the cutting of flux lines due to currents in the armature windings. It should be remembered that this e.m.f. is always such as to oppose the reversal of the current in the short-circuited coil.

Calculation of Short-circuit E.M.F.—Numerical Example.— In order to illustrate the manner in which the approximate value of the e.m.f. induced in the coil during short-circuit may be calculated, the dimensions and other particulars of the machine will be assumed as follows:

R. P. M. = 500
Number of poles $p = 6$
Diameter of armature core $D = 30$ in.
Ratio $\dfrac{\text{Pole arc}}{\text{Pole pitch}} = r = 0.625$
Length of armature core $l_a = 11$ in. $= 28$ cm.
Total number of slots $= 120$

---

[6] "Principles of Electrical Design," second edition, p. 155.

Number of slots per pole $n = 20$
Slot Pitch $\lambda = 0.785$ in.
Slot width $s = 0.39$ in.
Slot depth $d = 1.5$ in.
Style of winding: Full pitch, multiple.
Current per armature path $I_c = 76$ amp.
Number of conductors per slot $= 2T = 8$
Total number of armature conductors $Z = 120 \times 8 = 960$
Number of commutator bars $= 120$ (There are only two coil sides per slot, giving four turns between adjacent commutator bars.)
Diameter of commutator $= 20$ in.

Pitch of commutator bars $= \dfrac{\pi \times 20}{120} = 0.524$ in.

Number of bars covered by brush $= 1\frac{3}{4}$
Brush arc $W = 0.524 \times 1.75 = 0.916$ in.

Brush arc referred to armature periphery,

$$W_a = \frac{0.916 \times 30}{20} = 1.375 \text{ in.} = 3.5 \text{ cm.}$$

With the brushes exactly half-way between pole tips, and a total travel of the coil of $W_a = 1.375$ inches during the time of short-circuit, the total flux cut by each coil side, including one-half of the entire length of the end connections per coil, may be calculated by making use of the formulas for the three separate components of this flux.

By formula (3), the equivalent slot flux is

$$l_a \, \phi_{es} = 28 \frac{1.6\pi \times 1.5}{3 \times 0.39} \times 4 \times 76 = 55,000 \text{ maxwells.}$$

By formula (5), the armature flux which leaves the teeth in the zone of commutation of width W_a and length l_a is

$$W_a \, l_a \, B_a = 3.5 \times 28 \times \frac{960 \times 76}{7(1 + \frac{2}{6})(1 - 0.625)30} = 68,000 \text{ maxwells.}$$

The end flux is calculated by formula (6). We shall assume the factor k to have the value 2, and the pole pitch is

$$\tau = \frac{\pi \times 30 \times 2.54}{6} = 40 \text{ cm.} \quad \text{Then}$$

$$\phi_e = 0.3 \times 2 \times 3.5 \times 20 \times 4 \times 76 \sqrt{\frac{40}{3.5}} = 43,200 \text{ maxwells.}$$

The sum of these three components gives a total of 166,200 maxwells cut by one side of the coil of four turns in the time

$$t_c = \frac{W_a}{\text{peripheral velocity of armature}} = \frac{1.375 \times 60}{\pi \times 30 \times 500} = \frac{1}{572} \text{ sec.}$$

The average value of the e.m.f. generated in the short-circuited coil is therefore,

$$\frac{\text{Twice total calculated flux} \times \text{No. of turns in coil}}{10^8 \times \text{time of cutting (in seconds)}}$$

$$= 2 \times 166200 \times 4 \times 572 \times 10^{-8} = 7 \cdot 6 \text{ volts.}$$

This voltage, which opposes the reversal of current, may be annulled by providing commutating poles or by shifting the brushes so that the resultant of all fluxes cut by the coil during commutation shall be zero.

The surface resistance offered by carbon brushes will correct appreciable departures from the ideal conditions, so that an exact neutralization of all armature fluxes tending to oppose reversal of current is not necessary in modern continuous current machinery.

Brush Contact Resistance as an Aid to Commutation.—When copper brushes are used destructive sparking is likely to occur even when a comparatively small e.m.f. is induced in the short-circuited coil. The contact resistance of carbon brushes assists the reversal of current and thus allows of sparkless commutation, even with an appreciable departure from the ideal condition of zero value for the average short-circuit e.m.f. At the beginning and end of the commutation period the field in which the coil moves should be such as to produce an e.m.f. in the short-circuited coil of the value $e = I_c R$, where I_c is the current per path of the armature circuit and R is the resistance of the short-circuited coil. On the assumption of a uniform current density over the surface of the brush, the brush contact resistance need not be taken into account, as will be clear from the following considerations. Fig. 6 shows a brush of width W covering several segments of the commutator. The total current entering the brush is $2I_c$, and since the density is constant over the surface of the contact, the current entering the brush over any surface of width S is $2I_c \frac{S}{W}$. To calculate the volts e that must be developed in the coil of resistance R when the distance yet to be travelled before the end of commu-

tation is w, consider the sum of the potential differences in the local circuit $AabB$ which is closed through the material of the brush. This leads to the equation

$$e = i\,R - i_a\,R_a + i_b\,R_b \qquad (7)$$

where R_a and R_b are contact resistances depending upon the areas

FIG. 9.
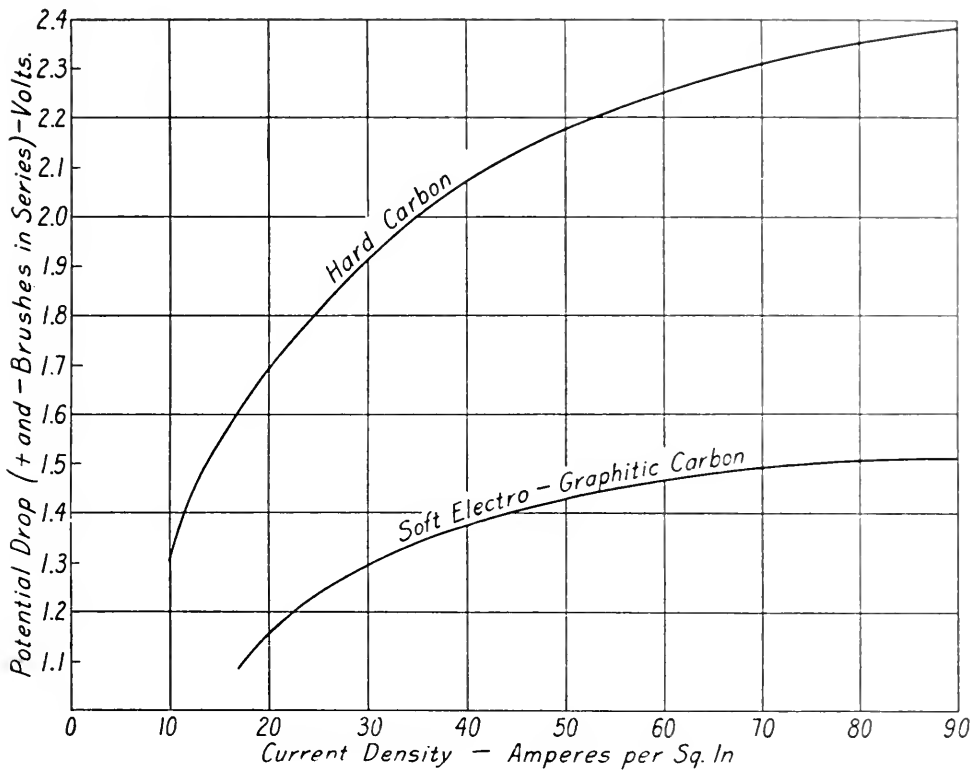
of the surfaces through which the current enters the brush. Under the conditions shown in Fig. 6, the two contact surfaces are equal, and the currents i_a and i_b are therefore also equal. It follows that the voltage drops $i_a R_a$ and $i_b R_b$ are equal and cancel out from the equation (7). The same may be shown to be true when the distance w yet to be travelled by the commutator is less than the width of the brush segment, and it therefore follows that, with " straight-line " commutation and the *uniform current density over the brush contact surface* which necessarily results from the " straight-line " law of current reversal, the only e.m.f. to be developed in the short-circuited coil is $e = iR$.

Thus, although the *average* short-circuit e.m.f. during the time of commutation should be zero, the ideal voltage in the coil

at the beginning and end of commutation is plus or minus I_cR irrespective of the material or contact resistance of the brush.

We shall now consider how, and to what extent, a departure from the ideal conditions is permissible when carbon brushes are used. In Fig. 7 the commutator is shown as having moved forward under the brush, leaving the distance w yet to be travelled before the segment A passes from under the brush considerably

FIG. 10.

smaller than in Fig. 6. If the current density under the portion w of the brush be allowed to exceed the density under the remaining portion of width $(W - w)$, the opposition to the passage of the current component i_a will increase and the greater potential drop at this point will assist in bringing the current i in the coil more nearly up to the value I_c, which it must reach at the instant the mica passes from under the brush. It is true that, under steady conditions, the contact resistance of carbon brushes decreases greatly with increase of current density, as indicated by the curves of Fig. 8, and it might be argued that, since the potential drop (see Fig. 9) is not very much greater with a density of 100 amperes per square inch than with a normal density of 40 amperes per square inch, the corrective effect of the contact resistance of carbon brushes must be very small. However, when the current density is rapidly fluctuating, even between wide limits, it

has been shown [7] that the specific contact resistance will remain approximately constant at all points under the brush.

Let R_c stand for the specific contact resistance of the carbon brush when the average current density per square inch of surface is $\triangle$; and let $\triangle_w$ be the greater current density in the space of width w (see Fig. 7) resulting from an induced voltage e in the short-circuited coil which opposes reversal of the current. Then

$$e = i R - \triangle_w R_c + \triangle R_c.$$

but as the space w becomes smaller and smaller, the current i_a decreases and i becomes more and more nearly equal to I_c, so that, for the condition at the end of commutation, we may write

$$e = I_c R - R_c (\triangle_w - \triangle).$$

Let k stand for the ratio $\dfrac{\triangle w}{\triangle}$, then

$$e = I_c R - R_c \triangle (k-1)$$

As an example, assuming an upper safe limit for $\triangle_w$ of 120 amperes per square inch and $\triangle = 40$, we have $k = 3$, and since $R_c\triangle$ is always about one volt, the permissible variation from the ideal value of $c = I_cR$ at the end of commutation is seen to be 2 volts. If this variation from the ideal voltage is exceeded, there is likely to be trouble due to sparking, even when carbon brushes are used. In practice the high contact resistance of carbon brushes will not only permit slight departures from the correct average value of the reversing field provided by commutating poles (or by the main poles when sparkless commutation is obtained by moving the brushes), but it will also take care of the pulsations and fluctuations in the short-circuit e.m.f., and so prevent great irregularities in the local current passing through the coil *via* the brush contact surface.

The permissible amount of variation from the ideal voltage in the short-circuited coil can be accurately determined only by actual test, because it will depend upon the particular grade of carbon used for the brushes, and other factors which cannot very well be taken account of in the calculations. There are very few designs of dynamos in which the carbon brush alone will bring about satisfactory commutation without the aid of a reversing field to counteract the flux set up in the zone of commutation by

---

[7] Hawkins and Wallis " The Dynamo," Fifth edition, p. 607.

the currents in the armature windings. Thus, in a previous example the average short-circuit e.m.f. was found to be $e = 7.6$ volts which greatly exceeds what could be taken care of by the contact resistance of carbon brushes. The resistance of the four turns of armature winding which form the short-circuited coil in the example referred to would probably not exceed 0.01 ohm, so that with the current $I_c = 76$ amperes, the ideal value for the

FIG. 11.
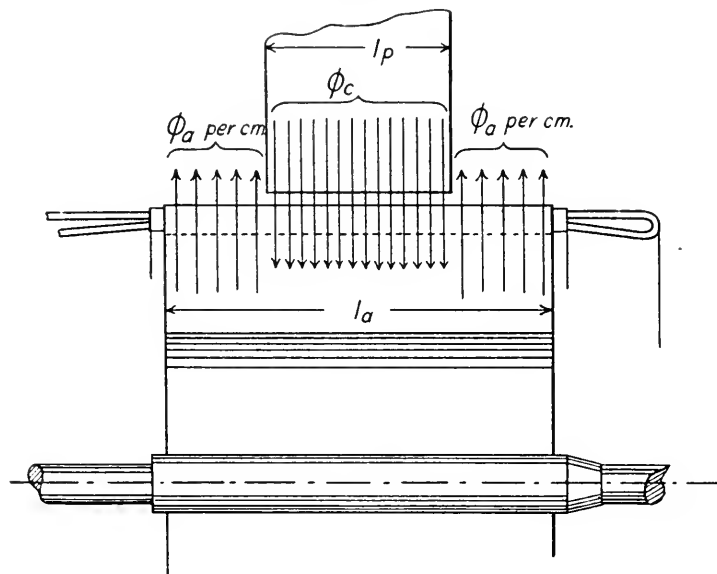
voltage in the coil at the end of commutation would be $e = 76 \times 0.01 = 0.76$ volt, and the difference $7.6 - 0.76 = 6.84$ volts could not be taken care of by the brush contact resistance. Assuming that a variation of 1.5 volts from the ideal value of the short-circuit e.m.f. is permissible, the machine would probably work sparklessly with carbon brushes commutating in the geometric neutral zone with a load of $\frac{1.5}{6.84}$ or (say) 22 per cent. of full load, if the pulsations in the local short-circuit current could be neglected. With a load exceeding 22 per cent. of rated full load it would, however, be necessary to resort to brush shift or provide commutating poles in order to obtain a reversing field and so counteract the effects of the various fluxes in the commutating zone which are due to the armature currents.

Commutating Poles.—These are auxiliary poles situated half-way between the main poles and excited by a series winding so

proportioned as to furnish the amount of flux necessary to coun-
teract the effect of the armature m.m.f.s in the zone of commu-
tation.   In machines furnished with commutating poles, the
portion of the armature periphery covered by the main poles is
usually limited to 0.62 or 0.65 of the total periphery.

FIG. 12.
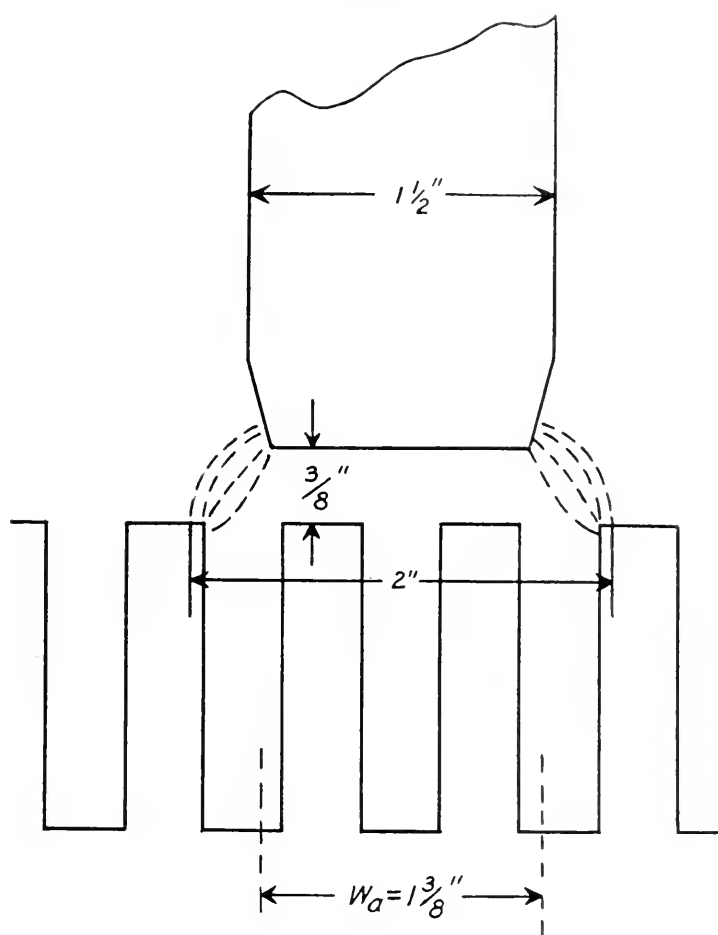
In Fig. 10 the face of the commutating pole is supposed to
cover the full length of the armature core and to be wound with
sufficient ampere-turns to overcome the armature m.m.f. and force
a certain amount of flux into the armature teeth comprised in the
zone of commutation.   In this case the flux required to balance
or counteract the flux cut by the end connections of the short-
circuited coil has been neglected, and the flux shown entering the
teeth under the commutating pole is the slot flux only.   If the
face of the commutating pole were shorter than the axial length
of the armature core (as is usually the case) there would also

be a certain amount of what has previously been referred to as the armature flux to be compensated for; but Fig. 10 has been drawn solely for the purpose of showing how the slot flux—which cannot be annulled like the armature flux—is supplied by the commutating pole, and since it no longer passes outward through the roots of the teeth, is not cut by the coil as it travels over the space of width W_a. When the conductors fill the slot instead of being concentrated at the bottom as shown in Fig. 10, a portion of the slot flux is cut by a portion of the conductors in the slot. It is therefore necessary to consider what shall be understood by the "equivalent" slot flux when this flux is supplied by the commutating pole (or leading pole tip when the brushes are shifted), because this will no longer have the same value as given by the previously developed formula (3).

The element of flux $d\phi$ (see Fig. 4) no longer links with $2T\dfrac{x}{d}$ conductors as when the slot flux was considered as passing outward through the roots of the teeth, but with $2T\dfrac{(d-x)}{d}$ conductors. The equivalent flux per centimetre axial length of slot when no part of this flux passes into the armature core below the teeth, is therefore

$$
\begin{aligned}
\phi'_{es} &= 2 \int_0^d d\phi \times \frac{d-x}{d} \\
&= \frac{1.6\,\pi\,TI_c}{d^2\,s} \int_0^d x\,(d-x)\,dx \\
&= \frac{1.6\,\pi\,d}{6\,s}\,TI_c
\end{aligned}
\tag{8}
$$

or just half the equivalent slot flux as given by formula (3), and one-third of the total slot flux as given by formula (2).

The question now arises: What is the necessary total flux entering the tops of the teeth comprised in the commutating zone to develop the proper voltage component in the short-circuited coil?

If the commutating pole is of the same length axially as the armature core, the flux cut by the coil side in the slot must be such as to generate an e.m.f. exactly equal but opposite to the e.m.f. developed by the cutting of the end flux ϕ_e, as this will produce

the desired condition of no change of flux through the coil during the time of commutation. If ϕ_a is the flux per centimetre of axial length passing into the armature through the roots of the teeth comprised in the zone of commutation of width W_a and length l_a, the total flux entering the armature teeth from the commutating pole is

$$\phi_c = (\phi_s + \phi_d) \, l_a. \tag{9}$$

The condition necessary to produce the "neutral field" of commutation is

$$\phi_e = (\phi'_{es} + \phi_d) \, l_a.$$

The quantity ϕ_s in equation (9) may be replaced by $3\phi'_{es}$ and a value for ϕ_d in terms of ϕ_e and ϕ'_{es} is obtained from the last equation. These substitutions lead to the equation

$$\phi_c = 2\phi'_{es} l_a + \phi_e \tag{10}$$

or, if preferred

$$\phi_c = \phi_{es} \, l_a + \phi_e. \tag{11}$$

Before discussing the more general case of an interpole of which the face does not extend the full length of the armature core, it will be advisable to group together and define clearly the various flux components which have to be considered.

ϕ_c = total flux entering armature teeth from interpole over area of width W_a and length l_p (see Fig. 11).

ϕ_e = end flux; being the amount of flux cut by the T_c conductors in the end connections of *one end* only of the armature.

ϕ_s = total slot flux per centimetre of armature length (two slots).

ϕ_{es} = equivalent slot flux per centimetre when magnetic lines pass outward from armature core through root of teeth (two slots).

ϕ'_{es} = equivalent slot flux per centimetre when magnetic lines pass inward from air gap through top of teeth (two slots).

ϕ_d = portion of interpole flux per centimetre length, which enters armature core through root of teeth.

ϕ_a = armature flux per centimetre length, which leaves teeth over the commutating zone of width W_a and length $l_a - l_p$ (Fig. 11).

The total amount of the armature flux is $\phi_a(l_a - l_p)$. It may be calculated by means of formula (4) or (5) which gives the quantity B_a, and ϕ_a is $B_a W_a$ where W_a is the width of the zone of commutation at the armature surface in centimetres.

Since the equivalent flux to be cut by conductors under the interpole must equal the total of all the flux components that have to be neutralized, we may write the equation

$$\phi_d \, l_p + \phi'_{es} \, l_p = \phi_e + \phi_a \, (l_a - l_p) + \phi_{es} \, (l_a - l_p).$$

The total flux in the air gap under the face of the commutating pole is

$$\phi_c = \phi_s \, l_p + \phi_d \, l_p.$$

Inserting for $\phi_d l_p$ in this last equation the value derived from the previous equation, we get

$$\phi_c = \phi_s \, l_p + \phi_e + \phi_a \, (l_a - l_p) + \phi_{es} \, (l_a - l_p) - \phi'_{es} \, l_p. \tag{12}$$

This equation may be simplified by expressing the total slot flux ϕ_s and the equivalent slot flux ϕ'_{es} in terms of the equivalent slot flux ϕ_{es}. The relation between these quantities is obtained by comparing previously developed equations. Thus we have,

$$\phi_s = \frac{3}{2} \, \phi_{es}$$

and

$$\phi'_{es} = \frac{1}{2} \, \phi_{es}.$$

Inserting these values in equation (12), we get

$$\phi_c = \phi_e + \phi_{es} \, l_a + \phi_a \, (l_a - l_p) \tag{13}$$

wherein the symbols ϕ_{es} and ϕ_a stand for the flux components *per centimetre length* of armature core, as previously defined.

Knowing the amount of flux to be provided by each commutating pole, its cross-section can be decided upon and the necessary exciting ampere-turns calculated, bearing in mind the following requirements:

(*a*) The average air-gap density should be low (preferably not exceeding 4000 gausses with full load on the machine), to allow of increase on overloads.

(*b*) The leakage factor should be as small as possible. This involves keeping the width and axial length of interpole small, thus conflicting with condition (*a*) and presenting one of the difficulties of commutating pole design.

(c) The minimum width of pole face must be such that the equivalent pole arc (which includes an allowance for fringing) shall be somewhat wider than the commutating zone of width W_a.

(d) The effect of the interpole being to increase the flux in that portion of the yoke which lies between the interpole and the main pole of opposite polarity, it is important to see that the

FIG. 13.

A B C
A' B' C'   Coil pitch = Pole pitch = N slots

Direction of motion of coils and commutator →

A' B' C'   A B C

Coil pitch = 3N Bars

$+I_c$ $+i_c$ $+I_c$ $+I_c$ $+i_c$

$-I_c$

Brush pitch = 3N Bars   Width W = 3½ Bars
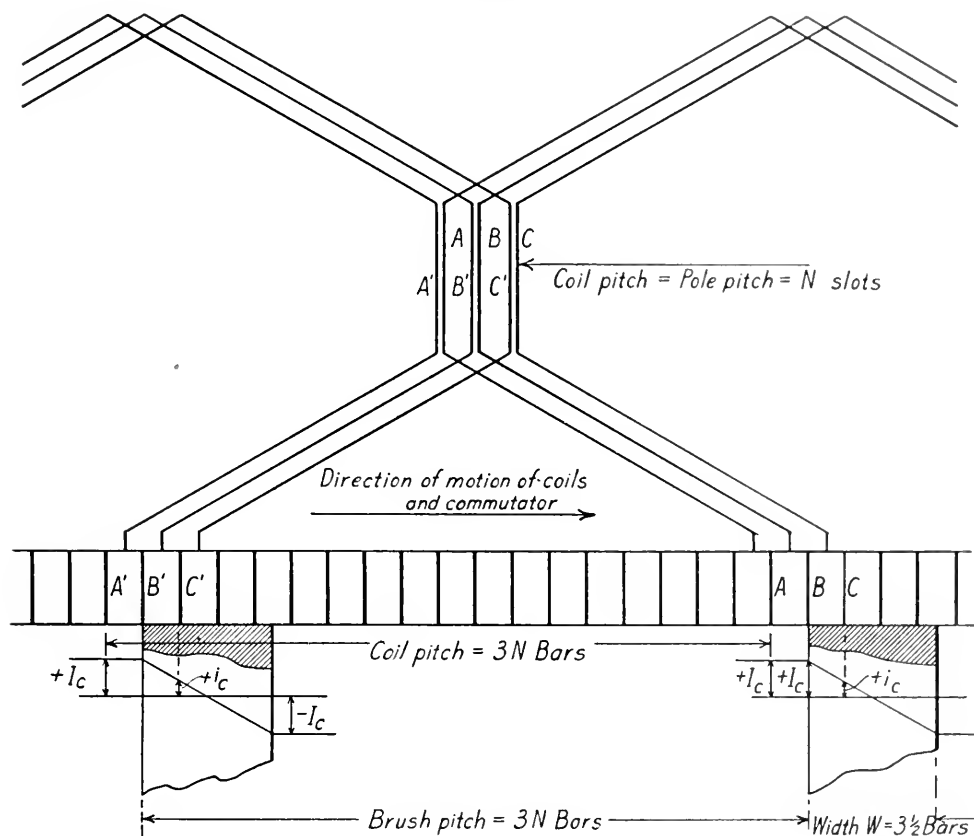
resulting flux density in this part of the magnetic circuit is not excessive.

(e) The total line current should, if possible, pass through all the interpole windings in series; that is to say, parallel circuits should be avoided because of the possibility that the current may not be equally divided. If the total current is too great, a portion may be shunted through a diverter. The diverter should be partly inductive, the resistance being wound on an iron core in order that the time constants of the main and shunt circuits may be approximately equal. If this is not done, the interpole winding will not take its proper share of the total current when the change

of load is sudden, and this may lead to momentary destructive sparking.

Example of Commutating Pole Design.—In order to avoid unnecessary repetition, the data previously assumed for the calculation of the short-circuit e.m.f. will be used. With the same number of interpoles as there are main poles (*i.e.,* six in this example) the flux entering the teeth in the commutating zone of width $W_a = 3.5$ cm. should have the value given by formula (13). The end flux cut by the short-circuited coils has already been calculated by formula (6) and has the value $\phi_e = 43,200$ maxwells.

The equivalent slot flux as previously calculated by formula (3) has the value $l_a\phi_{es} = 55,000$ maxwells.

The flux density, where the flux due to the armature currents leaves the armature in the space of width W_a and length $(l_a - l_p)$, as indicated by the arrows in Fig. 11, is calculated by formula (5) and has the value

$$B_a = \frac{960 \times 76}{7\left(1+\frac{2}{6}\right)(1 - 0 \cdot 625) \times 30} = 695 \text{ gausses.}$$

If $l_p =$ axial length of interpole (not yet determined), the total flux which must pass from interpole into armature teeth is

$$\phi_c = \phi_e + \phi_{es}\, l_a + B_a\, W_a\, (l_a - l_p)$$

which is simply formula (13) with the armature flux per centimetre of length expressed as $B_a W_a$ instead of ϕ_a. The axial length of the interpole face can, therefore, be determined if a suitable value for the average air-gap density under full-load conditions is assumed. Let B_p stand for this value; then

$$B_p\, l_p\, W_a = \phi_e + \phi_{es}\, l_a + B_a\, W_a\, (l_a - l_p)$$

whence

$$l_p = \frac{\phi_e + \phi_{es}\, l_a + B_a\, W_a\, l_a}{W_a\, (B_p + B_a)}. \tag{14}$$

With flux densities expressed in gausses, the dimensions must be in centimetres, and if B_p is taken as 4000 gausses, the length l_p of the interpole measured parallel with the axis of the armature is found by formula (14) to be almost exactly 10 cm. or (say) 4 inches.

The total flux in the air-gap under the commutating pole in the space of width $W_a = 1.375$ inches is

$$\phi_c = 43,000 + 55,000 + 695 \times 1.375 \,(11 - 4)\, 6.45 = 141,400 \text{ maxwells.}$$

Flux in Core of Interpole.—Assuming the cross-section of the commutating pole to be as shown in Fig. 12, the total flux will have to be carried by an iron core of cross-sectional area $1.5 \times 4 = 6$ square inches. The air-gap is $\frac{3}{8}$ inch and the pole face is slightly smaller in width than the pole core; the effective or equivalent area (including an allowance for fringing) through which the flux enters the armature teeth will be something less than $2 \times 4 = 8$ square inches or (say) 6.5 square inches. Since we must have 141,400 maxwells entering the space of width $W_a = 1.375$ inches we require a total flux in the air-gap of $141,400 \times \dfrac{6.5}{1.375 \times 4} = 167,000$ maxwells. The leakage factor is always high because of the small distance between the commutating pole and main pole. If this leakage factor has the value 1.8, the total full-load flux in the core of the interpole is $167,000 \times 1.8 = 300,000$ and the flux density in the iron is $\dfrac{300,000}{6 \times 6.45} = 7750$ gausses.

This is well below the "knee" of the B-H curve and allows of considerable overloading before saturation of the iron begins to limit the proportionality between interpole flux and the flux set up by the armature winding through the coils in the zone of commutation.

The ampere turns necessary to overcome the reluctance of the air-gap when the average air-gap density is 7750 gausses can easily be calculated by any of the approximate methods used by designers. To these ampere turns must be added the ampere turns to oppose and balance the armature m.m.f. It is not proposed to calculate the series winding required. A number of turns slightly in excess of the calculated number are put on the interpole, the final adjustment being made on test. A resistance—or diverter—may be used to shunt part of the current, or the strength of the reversing field may be adjusted by altering the reluctance of the magnetic circuit of the interpole. This may be accomplished without changing the length of the air-gap between pole face and armature by inserting non-magnetic distance pieces between yoke ring and commutating pole. If this

method is adopted the machine would be designed with two or three iron packing pieces clamped between the pole core and yoke. One or more of these would be removed and replaced by brass plates if it were found desirable to reduce the amount of the reversing flux.

Methods of Reducing Flux Pulsations under Commutating Poles.—Although the fixed position of the brushes relatively to

FIG. 14.
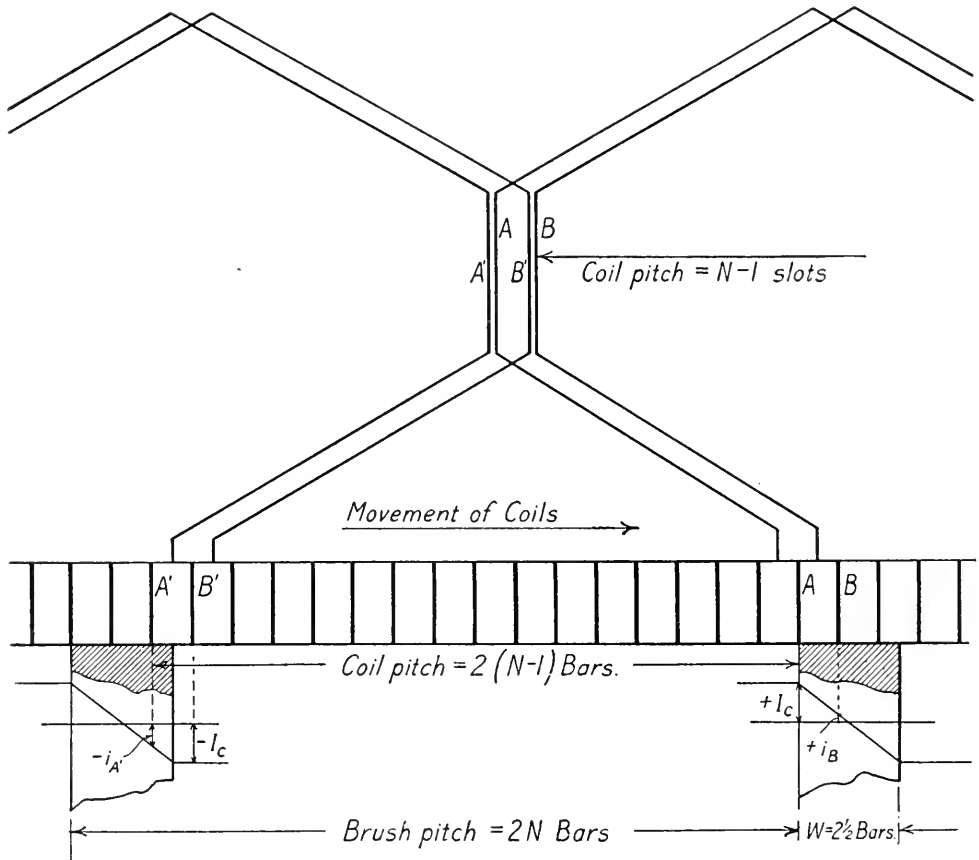
the field poles maintains the fluxes due to the armature windings generally in a fixed position in space, there will be certain oscillations and pulsations of flux which it is necessary to keep within limits that can be taken care of by the contact resistance of carbon brushes.

The amount of the flux oscillations under the interpole will depend upon the relative dimensions of pole face and tooth pitch and upon the angular width of the commutator bars, which should be kept small. By proportioning the face of the commutating pole

so that the reluctance of the air-gap varies as little as possible, whether a tooth or slot occupies the position under the centre of the pole, the flux pulsations due to variations in the reluctance of the magnetic circuit may be kept within reasonable limits. Obviously, a large tooth pitch is to be avoided, and the length of the air-gap under the interpole should be determined with this question of flux pulsations in mind. A narrow pole face and comparatively large air-gap will generally lead to good results.

FIG. 15.
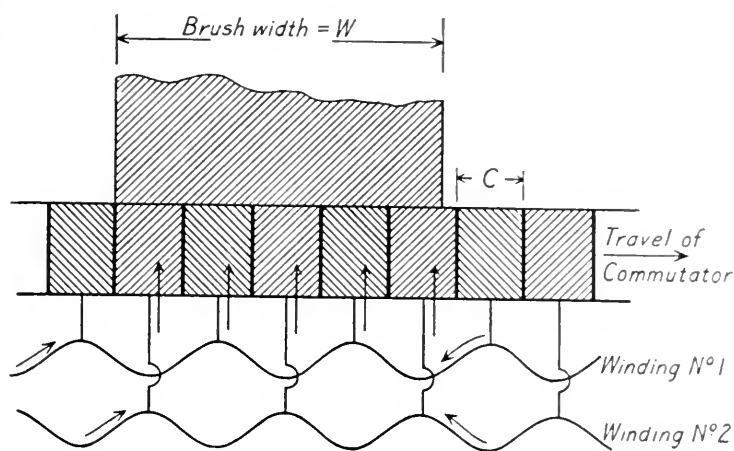
It is usually advisable to make the air-gap under the commutating pole about 25 per cent. longer than the gap under the centre of the main poles.

It has already been shown that the ampere turns on the commutating pole must be somewhat greater than the armature ampere turns which must be opposed and annulled before any flux can enter the armature from the commutating pole. In order to ensure equality of strength, the windings of the interpoles are usually all connected in series, which suggests that the armature m.m.f. is assumed to be of exactly the same amount under each interpole. With the series or two-circuit armature winding this condition is necessarily fulfilled, but with parallel windings the armature currents may not be perfectly balanced in the various circuits. That is the reason why series armature windings are generally to be preferred if there is likely to be any difficulty with commutation, but when proper provision is made for equalizing the currents in the armature circuits by means of a large number of equalizing connections satisfactory commutation may be obtained even with large parallel-wound armatures.

Effect of Several Coil-sides in One Slot—Full-pitch Windings.
—When developing formulas (2) and (3) for the slot flux and equivalent slot flux, two assumptions were made: (1) That the number of commutator segments was the same as the number of armature slots, and (2) that the coil pitch was the same as the pole pitch. When there are several coil sides per slot, which occurs when the number of commutator segments is a multiple of the number of slots, the current at the beginning and end of the commutation period has not the maximum value $+I_c$ and $-I_c$ in all the conductors occupying the slot for which it is desired to calculate the leakage flux. The slot leakage flux is then not correctly given by formulas (2) and (3), and, for a closer approximation to actual conditions, a modifying factor should therefore be introduced. In other words, a mean value for the current in the slot which sets up the leakage flux should be substituted for the maximum value I_c of the formulas (2) and (3).

By drawing a diagram such as Fig. 13, and assuming the change of current in the coils undergoing commutation to follow the "straight-line" law, it is an easy matter to calculate the required correcting factor. Fig. 13 illustrates the condition of a dynamo with full-pitch multiple winding, but with three times as many commutator bars as there are slots. There are six coil sides in the slot, the sides A, B, and C being (say) in the upper half, while the sides A', B', and C' are (say) in the lower half. The brush covers $3\frac{1}{2}$ commutator segments and the diagram shows the condition existing just as the coil B is about to be short-circuited by the right-hand brush at the beginning of the period of commutation. The average current in the slot conductors tending to set up leakage flux is seen to be no longer I_c but $\dfrac{4\,I_c + 2\,i_c}{6}$.

The value of i_c is $I_c - I_c\left(\dfrac{2}{3.5}\right)$, which gives for the average current per conductor at the beginning of commutation of the coil B the value $0.81\ I_c$. A similar calculation may be made for the coil B at the end of commutation at the instant when the mica B passes out from under the brush, and the remaining coils in the slot may be dealt with in a similar manner. The writer proposes the following formula to facilitate the calculations. If m

is the multiplier or correction coefficient by which the current I_c or the slot fluxes ϕ_s and ϕ_{cs} of formulas (2) and (3) must be multiplied, we have:

$$m = 1 - \frac{k-1}{2b} \qquad (15)^{[8]}$$

for full-pitch coils, where k = number of commutator bars per slot and b = number of bars covered by brush.

Formula (15) may be used whenever b is greater than k. For the special case of a very narrow brush when b is equal to or less than k, use the formula

$$m = \frac{b+1}{2k} . \qquad (16)$$

Effect of Short-pitch Winding on Slot Leakage Flux.— Although chord windings will usually slightly reduce the amount of armature flux in the zone of commutation and also the end flux, it is in the amount of the slot flux that their effect is most noticeable.

Fig. 14 is a diagrammatic representation of a chorded winding with the coil pitch one slot pitch shorter than the pole pitch, and with twice as many commutator bars as there are slots. There are four coil sides to the slot, and the figure shows the condition when the coil A is just about to be short-circuited by the brush, which covers $2\frac{1}{2}$ commutator segments. The average value of the current per armature conductor under these conditions is seen to be $\frac{1}{4}\left[I_c + i_B - I_c - i_A\right]$, a quantity which can be calculated on the assumption of the "straight-line" law of current reversal.

The formula proposed by the writer for a correction factor to take care of chorded windings, together with any number of coil sides per slot, is

$$m' = m\left[\frac{1}{2} + \frac{b - k(s-1)}{2(b+k)}\right] \qquad (17)$$

where m, b, and k have already been defined, and s is the number

---

[8] When k is greater than 2 a more correct formula for the average of all the coils in the slot is

$$m = 1 - \frac{5}{12}\left(\frac{k-1}{b}\right)$$

but it is suggested that the simpler formula (15) is sufficient for the needs of the designer.

of slots chorded, or the difference between the number of slots in the pole pitch and the number of slots spanned by the armature coil. For the winding illustrated by Fig. 14 we have $s = 1$. Formula (17) may be used for any value of s between $s = 0$ and

$$s = \frac{b}{k} + 1.$$

For special case of a very narrow brush, when b is equal to, or less than, k, the formula is

$$m = \left(\frac{b+1}{2k} \right) \left(0.5 + \frac{2-s}{4} \right) \tag{18}$$

which may be used for values of s between 0 and 2.

Numerical Example Illustrating Use of Formulas for Correction Factors.—In a previous example with slot dimensions $d = 1.5$ inch, $s = 0.39$ inch, and 8 conductors in the slot each carrying a maximum current of 76 amperes, the equivalent slot flux was found to be $\phi_{es} = 55,000$ maxwells. This was for a full-pitch winding with the same number of commutator bars as slots, namely 20 slots per pole and 20 commutator segments between + and − brush sets. Let us now calculate the slot flux on the basis of the same total ampere conductors per slot, namely $8 \times 76 = 608$, but with only two turns per coil (*i.e.,* twice as many commutator bars as there are slots), a brush covering 3 commutator segments, and a chorded winding with the coil spanning 18 slots. The quantities for use in the formulas (15) and (17) are then $k = 2$, $b = 3$, and $s = 2$, and

$$m' = \left(1 - \frac{k-1}{2b} \right) \left[\frac{1}{2} + \frac{b - k(s-1)}{2(b+k)} \right]$$

$$= \left(1 - \frac{2-1}{6} \right) \left[\frac{1}{2} + \frac{3-2(2-1)}{2(3+2)} \right]$$

$$= 0.5.$$

Whence the equivalent slot flux is no longer 55,000 maxwells as in the previous example, but half this amount, or 27,500 maxwells, which indicates that the amount of flux from interpole or leading pole tip to produce sparkless commutation will be less than with the full-pitch coils and the smaller number of commutator segments.

Duplex Windings.—In machines of very large current capacity the armature is sometimes wound with two circuits

connected in parallel by the brushes. The connections from any one winding to the commutator are then taken to alternate commutator segments, leaving the intermediate segments for connection to the other winding, all as indicated by the diagram, Fig. 15. The study of commutation in the rare cases when such double windings are used may be made on the same basis as for simplex windings, and the formulas (3), (15), and (17) may be used for slot flux calculations. Thus the reversing flux from the interpoles necessary to produce ideal commutating conditions will be approximately the same whether we have a simplex winding with two conductors per slot each carrying I_c amperes, or a duplex winding with four conductors per slot each carrying $\frac{1}{2}I_c$ amperes, and twice the number of commutator segments.

It should, however, be noted that the travel of the conductor on the armature periphery is no longer $W_a = W\dfrac{D}{D_c}$ which is a good enough definition of W_a for a simplex winding when the mica insulation between commutator segments is of negligible thickness. With the duplex winding it will be evident from a study of the diagram, Fig. 15, that we now have $W_a = (W - C)\dfrac{D}{D_2}$ where W = brush width, C = pitch of commutator bars, D = diameter of armature, and D_c = diameter of commutator.

For the same reason, namely, that the space between commutator segments of any one winding is the width of the bar pitch instead of merely the thickness of the mica, the time of commutation is

$$t_c = \frac{W - C}{V_c}$$

where V_c is the surface velocity of the commutator.

If the substitution of a duplex winding for a simplex winding involves not only the subdivision of the armature winding into two separate circuits connected in parallel by the brushes, but also the doubling of the number of slots, so that the ampere-conductors per slot are reduced to one-half what they would have to be with a simplex winding, it is obvious that the slot leakage flux may be considerably reduced, although little or no change will take place in the armature flux (or the density B_a of formula 4 or 5) and the end flux (formula 6).

Commutating Field Obtained by Brush Shift.—Little need be

said about commutation by moving the brushes in order to find under the main poles a magnetic field which will bring about proper reversal of the current in the commutated coils, because this method is little used at the present day. Graphical methods may be used to obtain a very close approximation to the true distribution of flux density in the air-gap under load conditions, and the problem then resolves itself into finding the brush position which will place the short-circuited coil in a reversing field of such strength as will satisfy the condition indicated by formula (11), which applies to an interpole covering the full length of the armature core.

Pole Face Windings.—It is not proposed to discuss the advantages and disadvantages of pole face windings, the main purpose of which is to compensate for field distortion due to the currents in the armature conductors. With brushes on the geometric neutral as in interpole machines, field distortion has very little to do with commutation; but obviously if a winding is provided in slots through the pole shoes to annul the cross-magnetizing ampere turns of the armature winding, the amount of winding necessary on the commutating poles will be greatly reduced. The problem of interpole design remains nevertheless practically unchanged because, if sparkless commutation is to be obtained, the amount of flux entering the armature in the zone of commutation must be the same whether or not pole face windings are used.

One advantage of compensating or pole face windings is the improvement of the " field form " and the avoidance of local flux concentration in the air-gap when the machine is heavily loaded. This greatly reduces the tendency to flash over at the commutator surface, a trouble which has very little connection with the reversal of current in the coil undergoing commutation.

Concluding Remarks.—Since this article deals mainly with the principles underlying the phenomena of commutation, many practical considerations which bear upon sparkless commutation have not been discussed. It is obvious, for instance, that the nature and peripheral velocity of the commutator surface, the hardness of the mica insulation, the quality of the carbon brushes, and many other factors of a similar nature must necessarily be considered in a complete study of the phenomena of commutation, and the designer is also interested in the mechanical construction and temperature rise of the commutator. The predetermination

of the load which a new design of machine will carry without injurious sparking is admittedly a difficult problem, and although formulas have been developed and their use explained, it is well to bear in mind that no general formula or method of attack will solve all problems of commutation. Special cases require special treatment, but once the underlying principles have been clearly recognized, such minor modifications in the formulas and calculations as may be necessary to suit individual cases can usually be made without involving any radical changes in the method of procedure.

On the Separation of the Isotopes of Mercury. J. N. BRONSTED and G. HEVESY. (*Phil. Mag.*, Jan., 1922.)—By his brilliant experiments Aston has laid a firm foundation for the belief that many substances hitherto regarded as elements are in reality not elements at all but are mixtures of isotopes, that is, of genuine elements whose atomic weights are not far apart and whose chemical properties are identical, or at least so nearly so that chemical methods are incompetent to separate the constituent isotopes. Mercury is such a substance, and these two investigators in the Polytechnic Institute of Copenhagen have addressed themselves to the task of finding whether pure, ordinary mercury can be divided into portions having a difference in some physical property. "Only a few methods of separation come into consideration—chiefly, those which make use of the difference in the molecular velocities (atomic velocities) appearing as a consequence of the mass difference of the isotopes." Two methods are selected for trial, those of evaporation and of effusion. If a liquid, made up of two isotopes, is in equilibrium with its vapor above it, then as many molecules of the first isotope escape from the liquid into the vapor per second as are changed from vapor into liquid in the same time by striking against the liquid and being there held fast. The same condition of equilibrium holds for the second isotope, but it would be wrong to conclude that in a second just as many molecules of the first isotope as of the second pass from the liquid into the vapor or that equal numbers of the two isotopes change in equal times from the vapor to the liquid phase. On the contrary, since the kinetic energy of a molecule of one isotope in vapor equals the kinetic energy of a molecule of the other in the same state and since, further, the masses of the two molecules are different, it follows that the molecule of the lighter constituent must move with a greater velocity. More molecules of this vapor will, therefore, impinge on the surface of the liquid in a given time, more will fail to get away, and, to maintain equilibrium, more of the same kind must escape from the liquid into the vapor. How can use be made of this difference to effect any separation of the isotopes? "This is

most easily accomplished by allowing the liquid to evaporate in a vacuum and placing a highly-cooled glass plate over its surface. Now when the vapor pressure of the liquid is sufficiently slight, each molecule which leaves the liquid will reach the cooled wall before it has had an opportunity of meeting other molecules and being thrown back into the liquid. Having reached the cooled wall, it will be held by it, transferred into the solid state, and hindered in re-evaporation." The mercury for the experiment was placed in the space between the inner and the outer flask of a Dewar bulb, which was well evacuated. Liquid air was put in the inner flask and the bulb was set in an oil bath at 40°-60°. The distance from the liquid mercury to the cold glass surface was from 1 to 2 cm. The mercury slowly evaporated and turned into a solid upon the glass. Later this distilled portion was separated from the residual liquid and the densities could then be determined, for density was the physical property in which the differences were sought. The residual mercury was treated again and again in the same manner until of the original 2704 c. cm. only .2 c. cm. had not evaporated. The densities were found to grow steadily greater as the process went on. Calling the density of the original mercury unity, that of the second residual was 1.000016; of the twelfth, 1.000079; and of the eighteenth, 1.00023. On the other hand, when the first distillate was subjected to a series of further distillations it became manifest that the density grew smaller and smaller. The first distillate had a value of .999977; the fifth, .999881; the fourteenth, .99974. The greatest density found seems to have been 1.00023 and the smallest, .99974, or a difference of 49 parts in 100,000, "corresponding to a difference of 0.1 unit in the element weight of mercury." (Element weight means the mean atomic weight of the mix-element.)

The second method of separation consists in heating mercury and letting the resulting vapor flow out and be condensed in two similar cold glass tubes. The vapor comes first to a tube whose orifice is covered with foil pierced with numerous tiny holes. The faster molecules of vapor will find their way in greater numbers through these holes so that the vapor which passes on and is later condensed in the second tube will be richer in the slower and heavier isotope. It appears that only a few experiments were made in this manner. The density of the liquid collected in the first tube was .999987, thus confirming the previous results.

The authors conclude "Our results agree with those of Aston's, found by means of his mass-spectrograph, in the fact that Aston found a strong line corresponding to the atomic weight 202 and an undissolved band the centre of which corresponds to about 199. A very slight quantity of an isotope with the atomic weight of 204, the presence of which follows from Aston's experiments, cannot be found by our method if the separation is not to be pursued very considerably farther."

G. F. S.

NOTES FROM THE U. S. BUREAU OF STANDARDS.*

THE FIELD RADIATED FROM TWO HORIZONTAL COILS.[1]

By G. Breit.

[ABSTRACT.]

In order to facilitate the landing of airplanes in times of poor visibility, Mr. J. A. Willoughby of the Bureau of Standards has suggested a special type of transmitting coil antenna.

This consists of two equal horizontal coaxial coils, one placed above the other. Both coils carry equal currents, and the current in one coil flows in a direction opposite to that of the current in the other.

It was believed that the waves would radiate in the form of a beam or inverted cone above the antenna. Experiments showed this to be true. The paper here abstracted concerns itself with the theoretical side of the question. In this paper the radiation from Mr. Willoughby's transmitting coil antenna is calculated.

The method of calculation is that of retarded potentials used in the form employed by Lorentz. The radiation is calculated for two cases, namely that of a circular coil and that of a rectangular coil.

By this method the value of the electric intensity is derived for points at distances from the transmitting coil antenna such as are of interest in actual practice.

It is found that if the effect of the earth is negligible, then an airplane carrying on its wings a receiving coil having its plane vertical receives a maximum of signal when it is situated in such a position that the line joining it to the transmitting coil antenna makes an angle of 30° with the vertical. The signal vanishes when the airplane is directly over the transmitting antenna and it vanishes rather soon after the airplane passes over the region of maximum signal and flies away from the transmitting antenna.

The effect on the transmission of having a perfectly conducting earth directly under the transmitting antenna has been investigated

---

* Communicated by the Director.
[1] Scientific Papers No. 431.

and it has been found that in this case a maximum signal is obtained when the line joining the airplane to the transmitting coil antenna makes 26° 34′ with the vertical.

In both cases the region of space within which the signal can be detected by receiving instruments of given sensibility has nearly the form of the space between two inverted coaxial vertical cones of finite length having their common apex at the transmitting station.

WEIGHING BY SUBSTITUTION.[2]

By C. A. Briggs and E. D. Gordon.

[ABSTRACT.]

The basic principle of " substitution weighing " is very simple. In general, the object to be weighed is placed on the platform of a scale and balanced. This load is then removed, and standard weights are substituted until the balance is restored. The standard weights needed for this are equal to the required weight of the object. The method has the important advantage that the effect of certain errors in the scale, otherwise affecting the results, can be eliminated. By observing certain precautions and details in the procedure very accurate results are possible, and this subject is covered in the present work.

This paper describes a plan for making substitution weighings which can be applied in using either equal-arm balances or compound lever scales. It is based upon the method developed by the Bureau of Standards in the test and standardization of the 10,000 pound weights which form a part of its railroad track scale testing equipments and in which a maximum accuracy is desired. The interest of the practical scale man coming in contact with the work of the Bureau has been aroused in its methods, and the present publication is prepared mainly in response to a general demand for an outline of a systematic method for carrying out substitution weighing. As the result of suggestions of these men engaged in the actual maintenance and testing scales, the procedure for taking data and conducting the routine of the test has been made to conform closely with that used by the Bureau of Standards in the precision test of railroad track and grain hopper scales; and the form for recording the data and making computations

---

[2] Technologic Papers No. 208.

which is presented has been arranged to be as near to that used in the scale-testing work as is practical.

It should be clearly understood that while the method was developed in connection with the testing of large weights, one of the fields of greatest usefulness is in the careful test of ordinary sized weights forming the working standards used by those testing scales and also for the test of counterpoise weights.

It is also believed that the publication will serve as a very useful reference for almost all industrial, engineering, or other technical laboratories where there is an occasional need for making weighings with more than ordinary accuracy. The paper offers a plan for undertaking such work promptly, as the steps to be taken and the record form and computation sheet to be used are presented in detail.

In the method of weighing by substitution presented in this publication readings are taken from the moving beam by means of a pointer and scale which are applied to the mechanism. The accuracy obtained is not limited by any error in the multiplication ratios of the weighing mechanism, but only by the precision with which it will repeat its indication.

The general matters covered by the paper comprise first a general description of the theory of weighing by substitution; the preparation of the scale for weighing so that the swings of the beam can be read on the graduated scale; the method for obtaining the positions of the equilibrium of the beam from the readings taken on it while moving; the method of removing and substituting weights; and a description of the details to be observed in preparing the scale and making observations, and the practice to be followed in making the computations.

The method is of especial value in the calibration of a large number of weights of the same denomination. The method is equally applicable, however, for determining accurately the unknown weight of any object.

A Study of Franklin's Experiment on the Leyden Jar with Movable Coatings. G. L. Addenbrooke. (*Phil. Mag.*, March, 1922.)—The usual form of this experiment is as follows: A glass jar has an inner and an outer metallic coating, both closely fitting and capable of being removed. This jar is charged in the regular way. The inner coating is removed by an insulated holder. It then has

scarcely any charge. It is touched to the outer coating which may be still in place or may have been separated from the glass. The two coatings are then put into position and it is found that the reconstituted jar has a strong charge. This is interpreted to mean that the seat of the charge was in the dielectric and that the charge remained there when the jar was taken apart.

The author of the paper could not reconcile the explanation with his views of electrical actions. He noted that glass was always mentioned as the material of the jar. He tried a jar of paraffin and found marked differences. Upon removal the inner coating had an electric charge. After the coatings had been touched and the jar put together, there was no appreciable charge left. Exactly the same results were obtained when precautions were taken to have the glass coatings free from moisture. It thus appears that in the experiment, as usually performed with glass as the dielectric, a damp layer on each side of the glass really serves as a coating. The removal of the coatings is, therefore, fictitious. The inner metal coating brings away with it only a little charge, the main part of the charge remaining behind on the damp layer.

It is suggested that the experiment be performed with the substitution of an ebonite or of a glass jar. The former should be kept in the dark with calcium chloride. The latter should be heated to 100° C. and kept with the hygroscopic substance as long as possible.

G. F. S.

Natural Gas in 1919. (*U. S. Geological Survey Press Notice.*)— The production of natural gas in the United States in 1919 was 11.8 per cent. more than in 1918. The figures for 1919, however, are not directly comparable with those for 1918, because the production in 1919 includes the volume of gas wasted in the fields and in transmission, as far as reported by the operators. The quantity of gas wasted is the difference between the quantity produced and that actually consumed, a difference of 58,943,631,000 cubic feet. As the figures for 1919 include this wasted gas, no value is given to the quantity produced. If the volume of gas wasted had been utilized it would have possessed a value of about $13,725,000. This quantity does not include the gas wasted at the point of consumption. The quantity produced in 1919, not including the gas wasted, is therefore the quantity consumed, which was 739,915,781,000 cubic feet, an increase of only 2.6 per cent. over 1918.

The total acreage reported in 1919 is considerably less than in 1918 and previous years because it includes only the acreage containing gas wells and that where gas wells predominate. The figures for past years included much of the oil acreage. It is impossible to separate the natural gas and petroleum acreage.

NOTES FROM THE RESEARCH LABORATORY EASTMAN KODAK COMPANY.*

ON CONVECTION EFFECTS IN PHOTOGRAPHIC BATHING OPERATIONS IN THE ABSENCE OF AGITATION.[1]

By E. R. Bullock.

THE relatively more rapid bleaching of a developed silver image on cinematograph film at the lower end of a strip immersed vertically in a ferricyanide-iodide solution was found to be a special case of a general phenomenon, which is seen with all silver images in gelatin or collodion on an impervious support when immersed vertically in any halidizing (halogenizing) bleach. By theoretical reasoning it was concluded that the phenomenon must be attributed to the effect of the existence of an upward convection current having its origin in the diminution of density of the bleach solution in contact with the image by the chemical reaction which takes place. Silver-dissolving solutions were found to act more rapidly at the upper than at the lower end of a vertically immersed silver image. The actual existence of upward convection currents during the action of halidizing bleaches, and of downward currents with silver-dissolving solutions, was demonstrated by the motions of suspended short lengths of cotton fibre. (A general method is thus available for the demonstration of the occurrence of a chemical reaction between a solid and a liquid. As an example, it was found that silver bromide reacts with a dilute potassium selenocyanide solution, and from this fact, with others, it was concluded that silver selenocyanide is less soluble than silver bromide, but more soluble than silver iodide.) In ordinary stand development (with vertical immersion and without agitation) a downward current prevails, and the rate of development is accordingly somewhat greater near the top than near the bottom of a negative. Under usual conditions the density difference due

---

to this cause is of the order of magnitude of 5 or 10 per cent. Convection currents during the fixing of bromo-iodide emulsions seem to harmonize with the view that, broadly speaking, the silver bromide dissolves before the silver iodide. It is probable that immediately after the disappearance of the last traces of opacity during fixing, the whole of the silver has been converted into the very soluble double thiosulfate.

Active Modifications of Hydrogen and Nitrogen Produced by Alpha Rays. F. H. NEWMAN. (*Phil. Mag.*, March, 1922.)—When an electric discharge passes through nitrogen or hydrogen it is found that these gases are absorbed when certain elements are present in the tube. At least in part the absorption is due to chemical action and seems to be caused by the production of active modifications of the gases. The present Lord Rayleigh found nitrogen drawn from the discharge tube to possess active properties and concluded that the active form was atomic in composition. Wendt has shown that the electric discharge in hydrogen at low pressures develops a modification of that element in which the molecule consists of three atoms. On the other hand, it is known that in a general way the chemical effects of alpha rays resemble those of the silent discharge. It seems, therefore, not unlikely that nitrogen and hydrogen under the action of these rays would comport themselves as they do when traversed by the electric discharge. The experiment has been tried by Mr. Newman and he finds that nitrogen after bombardment by alpha rays from polonium is little by little absorbed when sodium, potassium, sodium-potassium alloy, sulphur, phosphorus, iodine, arsenic, magnesium or mercury are present in the tube. The disappearance of the gas could not be due to occlusion, for upon heating it was not set free. This also indicates that any compounds formed are quite stable. After hydrogen had been treated in like manner it, too, was absorbed by sodium, phosphorus or iodine. Upon heating, however, it was re-liberated, indicating either occlusion or the formation of unstable compounds. A chemical test proved hydrogen sulphide to be formed when sulphur was in the hydrogen tube.

Neither ultra-violet light nor the radiation from polonium exclusive of alpha rays was competent to produce the same results as those achieved by the alpha rays.

G. F. S.

CRYSTALLINE CHLORO-TETRA-ACETYL MANNOSE.[1]

By D. H. Brauns.

[ABSTRACT.]

CHLORO-TETRA-ACETYL mannose, hitherto known only in the form of a syrup, has been obtained in crystalline form.

The behavior of the crystalline substance toward methyl alcohol and silver carbonate (reaction of Koenigs and Knorr) is analogous to that of bromo-tri-acetyl rhamnose. This is well accounted for by their structural formulas.

In the case of chloro-tetra-acetyl mannose, this reaction leads to various methyl tetra-acetyl derivatives and in this respect chloro-tetra-acetyl mannose differs from the corresponding derivatives of glucose and galactose, which yield only one methyl tetra-acetyl derivative.

This difference in behavior may lead to a more detailed knowledge of the arrangement of the constituent parts of their molecules.

OBSERVATIONS UPON THE RESISTANCE OF THE RAT TO CONSECUTIVE INJECTIONS OF STRYCHNINE.[2]

By E. W. Schwartze.

[ABSTRACT.]

THE tolerance of the rat to repeated subcutaneous injections of strychnine has been studied. Evidence has been adduced to show that the coefficients of disposal which are necessarily expressed in terms of percentage of minimum lethal dose per given period of two hours are too low. They should be reinterpreted to fit the case of oral administration in which large amounts are administered at once and in which type of experimentation the absorption of strychnine has an opportunity to keep pace with the disposal. Accordingly, the coefficient of disposal has been

---

* Communicated by the Chief of the Bureau.
[1] Published in *J. Am. Chem. Soc.*, **44** (1922), 401.
[2] Published in *J. Pharmacol.*, **19** (1922), 49.

regarded as constant and the absolute amount disposed of as a variable depending on the amount present. On this basis the disposal of strychnine by the rat may reach at least 1 mgm. per kilo per hour. This occurs only when the strychninization is kept constantly very close to the maximum limit, by absorption from the gastro-intestinal tract.

The coefficients as determined arithmetically have been checked by a new experimental criterion, namely, the relation of survivals to fatalities in a given uniformly treated series and comparison of one such series with another.

The extremely high tolerance of the rat (as well as of other animals) to consecutive injections of strychnine would seem to be significant with respect to the possibility of correlating this with the failure to demonstrate as yet an habituation to this drug.

BOTULISM FROM THE REGULATORY POINT OF VIEW.[3]

By Charles Thom.

[ABSTRACT.]

TRANSFORMED into concrete suggestions, responsibility for food poisoning, in so far as canned goods are concerned, rests about equally upon the dealer and upon the household. Every dealer should be made to feel a direct and positive obligation to remove from sale any can of food which shows sign of spoilage, and to condemn as dangerous and return to the packer any lot in which spoilage appears in considerable percentage. Correspondingly, some one, at least, in every household, should definitely understand the dangers of spoiled food, canned or uncanned, make intelligent examination of all food bought and apply discriminating care to all food stored in the home.

As a basis for propaganda to eliminate the danger of poisoning cases, these recommendations may be given the widest publicity.

(1) Clean, fresh, sound food will not cause botulism.

(2) Food freshly heated to the boiling point will not cause botulism.

(3) Recooking is advised whenever opportunity for microbial activity has been given, but only before spoilage becomes evident by appearance, odor or taste. Food showing signs of decom-

---

[3] Published in *Am. J. Public Health,* **12** (1922), 49.

position is potentially dangerous; hence physical evidence of spoilage should lead to destruction, not to salvaging.

(4) Intelligent coöperation of packer, dealer, and householder in the examination of food before it reaches the table is essential to the prevention of botulism.

RATIONS FOR FEEDING POULTRY FOR THE PACKING HOUSE.[4]

Contribution from the Food Research Laboratory.

[ABSTRACT.]

Extensive feeding experiments on both a laboratory and commercial scale showed that a great variety of feeds can be used in fattening broilers, springs, roasters, and hens. Numerous analyses of unfed and fed birds are recorded. Data are given on the weight lost by range and fed birds during dressing, on the percentage increase in weight of the different classes of birds receiving the experimental rations for fourteen days and of those fed the control ration of cornmeal (forty parts) and buttermilk (sixty parts) for four, eight, eleven and fourteen days, and on the character of gains made in fourteen days by the use of the control ration. The experiments show clearly that the growing birds require a different ration from that of the adult fowl. The merits of different feeds from the standpoint of their content in protein, fats, carbohydrates, salts, and vitamines are discussed.

Demonstration of the Protective Effect of a Colloid.—Prof. J. Newton Friend communicates to *Nature* the following experiment showing the effect of a colloid on chemical change. This is afforded by the precipitation of mercuric iodide on addition of the chloride to potassium iodide. If this is effected in fairly dilute aqueous solution, the unstable yellow form is first precipitated and rapidly turns from orange to red as it becomes converted to the more stable variety. If, however, the reaction is carried out in the presence of gelatin, say, one per cent., the liquid first turns momentarily yellow, due to the formation of colloidal mercuric iodide, then becomes turbid, and a beautiful canary color develops, which remains practically unchanged for half an hour or more, according to circumstances. Only very slowly does it change to the red polymorph. The protective colloid retards the growth of the yellow particles. Sunlight accelerates the

---

[4] *U. S. Department of Agriculture Bulletin,* issued March 13, 1922.

change markedly. With the aid of the ultra-microscope (one-half inch oil immersion) these changes may be seen clearly. Drops of gelatin and dilute potassium iodide are mixed under the coverglass and the ultra-microscope focussed as usual. A drop of mercuric chloride solution is brought to the edge of the coverglass and is drawn under by capillary action. The field of the ultra-microscope becomes swept with a stream of luminous particles moving with dazzling velocity—the Brownian movement of the colloidal mercuric iodide. The velocity slows down as the particles increase in size, until the colloid range has been passed, and in a few minutes a fine precipitate is obtained evincing scarcely any movement.

H. L.

The Theory of the Intrinsic Field of a Magnet and the Relation of Its Magnetic to Its Characteristic Electric and Thermal Properties. J. R. ASHWORTH. (*Phil. Mag.*, March, 1922.)—For the explanation of the phenomena of ferro-magnetism, Pierre Weiss and others have assumed the existence of a magnetic field of force within the magnetic material. If the value of this intrinsic field be calculated from the relations between magnetic intensity and temperature, it appears to have an enormous value, while, if, on the other hand, it be derived from the effects of the application of an external magnetizing field, it comes out quite small. The large value has been in favor because it conveniently explained certain effects.

When ferro-magnetic substances are heated to the critical temperature, they lose their remarkable magnetic qualities and degenerate into mere paramagnetic materials. At about the same temperature there are likewise notable modifications in their electric resistivity, thermo-electric power and specific heat. It seems a fair assumption that the changes in these three properties are bound up with the disappearance of the intrinsic field at the critical temperature and, further, could the critical temperature with the accompanying loss of the intrinsic field be by some means shifted to some other temperature then these three properties also should show changes in the temperatures at which they manifest themselves, and this all the more if the intrinsic field is very strong. Happily there is a way of shifting the critical temperature in the case of nickel. The application of an alternating field to this metal reduces the critical temperature by from 50 to 100 degrees C. Experiments were made, and it was found that there was no corresponding displacement in the temperatures at which changes in the three properties occur. This indicates, though it does not prove, that the intrinsic field obliterated at the critical temperature is not so large as has been thought.

The author regards the intrinsic field as made up of two constituents, a molecular field of great strength and a magnetic field of small strength. Such a composite field has the advantage of explaining quite a number of magnetic effects. G. F. S.

NOTES FROM THE U. S. BUREAU OF MINES.*

COMPARISON OF TWO METHODS OF DETERMINING FUSIBILITY OF COAL ASH.

By A. C. Fieldner, W. A. Selvig and W. L. Parker.

THE micropyrometer method for determining coal-ash fusibility is more rapid than the gas-furnace method and is more comfortable to the operator. Coal ashes fusing under 2600 degrees F. by the gas-furnace method can in the majority of cases be checked within 100 degrees F. by the micropyrometer method if fused in a reducing atmosphere of combustion gases similar to that employed in the gas-furnace method. Very refractory ashes, fusing above 2800 degrees F. as determined by the gas-furnace method, tend to give considerably lower results by the micropyrometer method. The two methods can therefore not be considered as strictly alternate methods for all ashes. The great majority of coal ashes from American coals, however, fuse below 2800 degrees F. in the gas-furnace.

This subject is discussed in greater detail in a paper presented before the meeting of the American Chemical Society, in April, at Birmingham, Alabama.

TESTS OF HAND EXTINGUISHERS ON ZINC-DUST FIRES.

By S. H. Katz and J. J. Bloomfield.

FIRES in zinc dust sometimes give particular trouble, owing to their resistance to extinguishing, and the liability of explosions. Tests were made on commercial zinc dust with various extinguishers. Water aggravated the fire and increased the danger, as did sodium bicarbonate solution. Carbon tetrachloride, and silicon tetrachloride produced dense smoke. A " frothy mixture " was the best, smothering the flame quietly and effectively. Further details are given in a paper issued by the Bureau in mimeograph form.

---

* Communicated by the Director.

PHYSIOLOGICAL EFFECTS OF EXPOSURE TO LOW CONCENTRATIONS OF CARBON MONOXIDE.

By R. R. Sayers, F. V. Meriwether and W. P. Yant.

The effect of comparatively low concentration of carbon monoxide for short periods and under normal air conditions of temperature and humidity, with the subject at rest, was studied by Dr. Yandell Henderson and his co-workers. In making recommendations to the New York and New Jersey tunnel commissions he advised that, if the New York-New Jersey vehicular tunnel be so ventilated that persons passing through the tunnel would be exposed to not more than 4 parts of carbon monoxide in 10,000 parts of air for not longer than 45 minutes, they would experience no ill effects. Supplementary experiments, carried out by us in connection with our studies at the Bureau of Mines experiment station at Pittsburgh, substantiated this advice.

In continuing our studies on low concentrations of carbon monoxide, we made a few experiments in a specially constructed gas chamber where the conditions could be accurately controlled. The factors investigated were: (1) The effect of long exposure in low concentrations of carbon monoxide; (2) The effect of strenuous exercise; (3) The effect of high temperature and humidity in low concentrations of carbon monoxide.

The " work " was done on a bicycle ergometer and calculated as foot pounds. The carbon monoxide was made by dropping formic acid into hot concentrated sulphuric acid and purified by passing through a soda-lime canister. The composition of the gas used was 99.0 per cent. and 1 per cent. air. Analyses were made of blood samples taken from time to time, and record was kept of the body temperature, pulse, and general condition of the subject.

Results of the tests are summarized below:

With the subject at rest:

1   The exposure for 6 hours to 2 parts of CO in 10,000 caused:
  (a) saturation of 16 to 20 per cent. of the hemoglobin of the blood with CO;
  (b) very mild subjective symptoms of CO poisoning at the end of the test;
  (c) no noticeable effects after the test.

2   The exposure to 3 parts of CO caused:
   (a) saturation of 22 to 24 per cent. of the hemoglobin with CO after 4 hours, and 26 to 27 per cent. after 5 hours;
   (b) symptoms at the end of 2 hours absent; after 4 hours, mild effects attributed to CO poisoning; and after 5 hours, moderate effects;
   (c) after-effects of 4 hours' exposure mild; of 5 hours' exposure, moderate.

3   The exposure to 4 parts of CO in 10,000 caused:
   (a) saturation of 15 to 19 per cent. of the hemoglobin with CO at the end of 1 hour, and 21 to 28 per cent. at the end of 2 hours;
   (b) after-effects, moderate to marked.

With the subject exercising strenuously:

1   The exposure for 1 hour to 2½ parts of CO in 10,000 caused:
   (a) saturation of 14 to 16 per cent. of the hemoglobin with CO;
   (b) moderate symptoms of CO poisoning at the end of the test;
   (c) after-effects mild to moderate.

2   The exposure for 1 hour to 4 parts of CO in 10,000 caused:
   (a) saturation of 23 per cent. of the hemoglobin with CO;
   (b) moderate symptoms of CO poisoning;
   (c) moderate after-effects.

Further details are given in a recent report issued by the Bureau.

———

Synthetic Indigo.—A new synthesis of indigo is described by G. C. Bailey and R. S. Potter (*Jour. Am. Chem. Soc.*, 1922, xliv, 215–216). They used fumaric acid, prepared from maleic acid, as their raw material. Fumaric acid was converted into symmetrical dibromsuccinic acid by treatment with bromine and glacial acetic acid, under pressure at a temperature of 100° C. for 7 hours. The dibromsuccinic acid was converted into symmetrical dianilido-succinic acid by treatment with aniline. Three hundred grams of an equimolecular mixture of sodium hydroxide and potassium hydroxide were dehydrated by heating at a temperature of 450° C. for two and one-half hours in a closed agitated iron pot. Then 30 grams of sodamide were added, and a current of anhydrous ammonia was

passed through the pot. Twenty-five grams of sodium dianilido-succinate were added to the fused mass, and a temperature ranging from 230° to 240° C. was maintained for one and one-half hours. The resulting mass was dissolved in water, and air was blown through the solution. A precipitate of indigo formed and was collected on a filter. The indigo was 96.5 per cent. pure, and possessed satisfactory dyeing properties. The amount of indigo obtained was 60.4 per cent. of the theoretical yield from dianilidosuccinic acid, and 25 per cent. of the theoretical yield from fumaric acid.

J. S. H.

Death Valley, California. (*U. S. Department of Agriculture, Press Service Sheet No. 200.*)—Ten years of records obtained at the United States Weather Bureau substation at Greenland ranch in Death Valley, California, indicate that this is the hottest region in the United States, and probably on earth. The average of extreme maximum temperature reported to the Department of Agriculture since 1911 has been 125° F. At Greenland ranch temperatures of 100° F. or higher occur almost daily during June, July, and August. The hottest month on record is July, 1917, when the mean temperature was 107.2° F. But the temperature of 134° F. observed on July 10, 1913, is believed by meteorologists to be the highest natural-air temperature ever recorded with a standard tested thermometer exposed in the shade under approved conditions.

Death Valley is from two to eight miles wide and about 100 miles long, lying between high mountain ranges. It is the deepest depression in the United States, some estimates placing its lowest point at 337 feet below sea level. Greenland ranch is 178 feet below sea level. White people find the midsummer heat intolerable, and even the Indians go up to the Panamint Range during July and August.

The normal annual precipitation in Death Valley is less than two inches. Successful agriculture can not be maintained on less than 15 or 20 inches of annual precipitation without the aid of irrigation. A group of springs serve as the source of irrigation-water supply for Greenland ranch. The water has a temperature of about 100° F. and is only sufficient to irrigate 70 acres. Four crops of alfalfa are gathered each year. The principal product of the ranch is dressed meat, but experiments are being made in raising poultry and in growing vegetables, dates, citrus, and deciduous fruits.

THE FRANKLIN INSTITUTE.

(Proceedings of the Stated Meeting held Wednesday, April 19, 1922.)

HALL OF THE FRANKLIN INSTITUTE,

PHILADELPHIA, April 19, 1922.

DR. WALTON CLARK, President of the Institute, *in the Chair.*

The Board of Managers submitted its report. The report recorded the election to membership of:

Joseph M. Emerick, Esq., Office Manager—John T. Windrim, Architect,
   Commonwealth Building, Philadelphia, Pennsylvania.
John Irvin Bright, Esq., Architect,
   Otis Building, Philadelphia, Pennsylvania.
J. Heron Crosman, Jr., Esq., Vice-President,
   The Bell Telephone Company of Pennsylvania, Philadelphia, Pennsylvania.
Frederic H. Garrigues, Esq., Mathematician,
   Penn Mutual Life Insurance Company, Philadelphia, Pennsylvania.
L. H. Kinnard, Esq., President,
   The Bell Telephone Company of Pennsylvania, Philadelphia, Pennsylvania.
Howard S. Levy, Esq.,
   Philadelphia, Pennsylvania.
Louis Williams McKeehan, Esq., B.S., M.S., Ph.D., Research Physicist,
   Western Electric Company, New York City, New York.
Frederick J. Pearson, Esq., Technical Engineer,
   Chicago, Illinois;
lectures before the Sections by

R. B. Moore, D.Sc., Chief Chemist,
   Bureau of Mines,
      · Department of the Interior,
         Washington, District of Columbia,

on "Low Temperature Research and the Cryogenic Laboratory of the Bureau of Mines"; by

Harvey Fletcher, Ph.D.,
   Research Laboratories,
      The American Telephone and Telegraph Company,
         New York City, New York,

on "Nature of Speech and Its Perception"; by
E. W. Washburn, Ph.D.,
   Department of Ceramics,
      University of Illinois,
         Urbana, Illinois.

on "Physical Chemistry and Ceramics";

lecture before the Stated Meeting March 15, 1922, by

M. deKay Thompson, Ph.D.,
Associate Professor of Electrochemistry.
Massachusetts Institute of Technology,
Cambridge, Massachusetts,

on "Recent Progress in Applied Electrochemistry";
and additions to the library by gift, 26 volumes and 139 pamphlets, by purchase, 73 volumes and by binding, 28 volumes.

The Chairman then announced that the next business of the meeting would be the presentation of medals and certificates to gentlemen whose inventions had been examined by the Committee on Science and the Arts and found worthy of recognition by the Institute. He then recognized Mr. Henry B. Allen, who introduced Mr. Samuel T. Freas, of Trenton, New Jersey, recently awarded the Edward Longstreth Medal for his "Interlocking" Tooth Saw.

Mr. Allen said, "Mr. President: One often hears it said of a successful invention how surprising it is that no one thought of it before, it being so simple. In reality surprise should be expressed that anything so simple was thought of at all.

"In the present instance there has been produced a detachable tooth saw for cutting metal, the success of which results largely from its remarkable simplicity. This simplicity of design is due to no mere chance, but has behind it years of concentrated application to the study of metal cutting.

"The use of circular saws for cutting metal, while not new, is becoming increasingly extended. The inserted tooth saw allows faster and more economical cutting, but the intense stresses set up in the teeth of a saw doing heavy work has made it a difficult problem to hold the teeth in place, and at the same time readily removable and replaceable. The medalist has done this by a very simple but unusual combination of wedges.

"It is in consideration of this excellence of design resulting in the extended and successful commercial use of this saw that The Franklin Institute, through the Committee on Science and the Arts, has awarded the Edward Longstreth Medal to Samuel T. Freas, Esquire, of Trenton, New Jersey.

"It gives me great pleasure to present to you Mr. Freas, inventor of the ' Interlocking ' Tooth Saw."

The President presented the Medal, accompanying Certificate and Report to Mr. Freas, who thanked the Institute for the high honor conferred upon him.

Mr. George H. Benzon, Jr., was then recognized and described the Automatic Die Cutting Machine invented by Mr. Joseph F. Keller, of Brooklyn, New York, who had recently been awarded the Edward Longstreth Medal for his invention.

Mr. Benzon addressed the President as follows: "Mr. President: I believe I can say without fear of contradiction that the keynote of modern manufacturing is quantity production. I may also state that of the articles coming under this classification, a very large percentage are made in metal dies or molds. From the foregoing statements a slight appreciation of the importance of metal dies in the industrial world may be formed.

"Mr. Joseph F. Keller, who is with us this evening, has developed a series of machines known as the Keller Automatic Die Cutting Machines, which

automatically cut the metal dies to their various shapes under the supervision of an average mechanic, where ordinarily the skill of an especially trained man is required. These machines do the work more efficiently and save a considerable amount of time.

"In view of the improvements made by Mr. Joseph F. Keller in the art of mechanical die cutting, the Institute acting through its Committee on Science and the Arts has awarded to him the Edward Longstreth Medal.

"Mr. President, I have the honor of introducing Mr. Joseph F. Keller."

The President presented the Medal, accompanying Certificate and Report to Mr. Keller, who thanked the Institute for the high honor conferred upon him.

The paper of the evening on "The Structure and Building of Atom Nuclei" was presented by Dr. William D. Harkins, of the Department of Chemistry, University of Chicago, Chicago, Illinois. The speaker stated that the atom seems to consist of a central positive nucleus, which plays the part of the sun in the solar system, surrounded by a system of negative planetary electrons. The number of these planetary electrons is equal to the charge of the nucleus.

If an atom loses one or more of its planetary electrons, it easily picks up other negative electrons and becomes ·restored to its initial condition. However, if the nucleus is broken up, no known experimental means suffice to put it together again; so the atom is said to disintegrate only when the nucleus is broken apart.

The lightest of all atoms, that of hydrogen, consists of one hydrogen nucleus with one positive charge, or what will be termed a positive electron which carries practically all of the mass of the atom together with a planetary system consisting of one negative electron. All of the heavier or complex atoms seem to have nuclei which are built up from a number of positive electrons equal to the atomic weight, together with about half as many negative electrons which serve to bind them together.

The conditions under which an atom nucleus is stable were discussed. The principal stability conditions are very simple. The most stable nuclei contain an even number of both negative and positive electrons, the more important condition being that the number of negative electrons shall be even. Light atoms are in general more stable than heavy ones, though there are more types of heavy than of light atoms.

One of the most important of the stability conditions is that as the positive charge on the nucleus becomes larger the ratio of negative to positive charges in the nucleus must also become larger. That is, as the net positiveness of the nucleus increases the relative negativeness must also increase.

If the complete history of the building of atoms could be unfolded, it would undoubtedly be seen to be one of fundamental importance in determining the present condition of the stars, and also of the surface of the earth and the organisms which dwell upon it.

That elements may be split apart into isotopes has been found recently. The first isotopes separated, those of chlorine, were exhibited. The subject was illustrated by lantern slides, models and specimens.

A unanimous vote of thanks was extended to the speaker and the meeting adjourned.   R. B. OWENS,
                                                        Secretary.

COMMITTEE ON SCIENCE AND THE ARTS.

(Abstract of Proceedings of Stated Meeting held Wednesday, April 5, 1922.)

HALL OF THE INSTITUTE,
PHILADELPHIA, April 5, 1922.

DR. JAMES BARNES *in the Chair.*

The following reports were presented for final action:

No. 2783: " Interlocking " Tooth Saw. The Edward Longstreth Medal
to Mr. Samuel T. Freas, of Trenton, New Jersey.

Literature: On the recommendation of the Sub-Committee on Literature,
the following awards were made:

No. 2787: The Howard N. Potts Medal to Dr. Richard B. Moore,
Chief Chemist, Bureau of Mines, Department of the In-
terior, Washington, D. C., for his paper on " Helium, Its
History, Properties and Commercial Development " printed
in the issue of the JOURNAL OF THE FRANKLIN INSTITUTE
for February, 1921.

No. 2788: The Certificate of Merit to Rear Admiral W. H. G. Bullard,
Director, Naval Communication Service, Navy Department,
Washington, D. C., for his paper on " The Application of
Radio to Navigation Problems," printed in the JOURNAL OF
THE FRANKLIN INSTITUTE for June, 1921.

No. 2789: The Certificate of Merit to Dr. Charles E. Mendenhall,
of the University of Wisconsin, Madison, Wisconsin, for
his paper on " Aeronautic Instruments," printed in the
JOURNAL OF THE FRANKLIN INSTITUTE for January, 1921.

The following reports were presented for first reading:

No. 2780: Rich System of Detecting and Extinguishing Marine Fires.
No. 2786: Postage Meter.

R. B. OWENS,
Secretary.

SECTIONS.

Section of Physics and Chemistry.—A meeting of the Section was held
in the Hall of the Institute on Thursday, March 2, 1922, at eight o'clock, P.M.,
with Dr. Thomas D. Cope in the Chair. The minutes of the previous meeting
were approved as read.

Colonel E. Lester Jones, A.M., Director of the United States Coast and Geo-
detic Survey and Commissioner, International Boundary, United States-Alaska
and Canada, delivered a lecture on "Surveying from the Air." The standard sur-
veying methods of the United States Coast and Geodetic Survey were described;
and the history of aerial surveying was outlined. An account was given of the
aerial surveys of Atlantic City, the coast of New Jersey and the delta of the
Mississippi River. The lecture was illustrated with lantern slides. The com-

munication was discussed; on motion of Mr. W. H. Fulweiler a vote of thanks was extended to Colonel Jones; and the meeting adjourned.

                                                    JOSEPH S. HEPBURN,
                                                                Secretary.

Section of Physics and Chemistry.—A meeting of the Section was held in the Hall of the Institute, Thursday, March 23, 1922, at eight o'clock, P.M., with Dr. Harry F. Keller in the Chair. The minutes of the previous meeting were read and approved.

R. B. Moore, Sc.D., Chief Chemist, Bureau of Mines, United States Department of the Interior, delivered an address on "Low Temperature Research and the Cryogenic Laboratory of the Bureau of Mines." A résumé was given of the history of the liquefaction of gases with special reference to air, hydrogen, and helium. The application of low temperature work to physical constants and to the knowledge of the constitution of matter was described. The lecture was illustrated by lantern slides and experiments.

The communication was discussed at length; a vote of thanks was extended to Doctor Moore; and the meeting adjourned.

                                                    JOSEPH S. HEPBURN,
                                                                Secretary.

Electrical Section.—A meeting of the Section was held on Thursday evening, March 30, 1922, at eight o'clock, with Dr. James Barnes in the Chair.

Harvey Fletcher, Ph.D., of the Research Laboratory of the American Telephone and Telegraph Company and Western Electric Company, Incorporated, New York City, presented the paper of the evening on the "Nature of Speech and Its Perception." The relative importance of various frequency ranges in spoken sounds were translated into the electrical form. The electrical communication circuit used was the most nearly perfect ever devised. Electric wave filters were employed to eliminate at will various parts of the scale of speech frequencies. The intelligibility, characteristic of any condition of speech communication, was determined by test employing scientifically chosen syllables. The experimental results given exhibited in quantitative terms the effects of using limited ranges of frequency to transmit speech. The data was analyzed so that the specific action upon each vowel and consonant was plainly evident. The evidence thus obtained would seem to demand a modification of the present theories of speech.

The subject was illustrated by numerous experiments and lantern slides.

A unanimous vote of thanks was extended to the speaker and the meeting adjourned.

                                                    ALFRED RIGLING,
                                                            Acting Secretary.

ASTON LECTURES.

Under the Auspices of the Bartol Research Foundation of The Franklin Institute.

Dr. F. W. Aston, F.R.S., Fellow of Trinity College, Cambridge, England, delivered a series of lectures on "Atomic Weights and Isotopes" in the lecture hall of the Institute on the afternoons of March 6th to 10th, inclusive.

The first lecture was delivered on the afternoon of Monday, March 6th, at 3.30 o'clock. Mr. Coleman Sellers, Jr., Vice-president of the Institute, welcomed Doctor Aston, and Dr. Arthur W. Goodspeed, Professor of Physics, University of Pennsylvania, M.F.I., presided. The subject of this lecture was "The Atomic Nature of Matter" and the following is a brief synopsis:

The atomic structure of matter generally; ancient speculation. "Is matter infinitely divisible?" Views of Newton and the early chemists. Dalton's atomic theory. Size and number of atoms illustrated by repeated subdivision of a cube of lead. Relative delicacy of methods for the detection of elements. Modern methods of detection of single atoms.

Dr. Augustus Trowbridge, Professor of Physics, Princeton University, M.F.I., presided at the second lecture on Tuesday, March 7th. Subject, "Discharge of Electricity in Gases." Special attention was given the following:

Nature of low-pressure discharge. Crookes' dark space, its length at different pressures in various gases, variation with current intensity. Primary dark space. Distribution of potential in the Crookes' dark space. Failure of theories suggested. Cathode rays and positive rays.

Mr. W. H. Fulweiler, Chief Chemist, United Gas Improvement Company, Philadelphia, M.F.I., presided at the third lecture on Wednesday, March 8th. Subject, "Positive Rays and Their Analysis." Special attention was given to the following:

Sir J. J. Thomson's parabola method of analysis of positive rays. First proof of the approximate identity of weights of atoms of the same element. Abnormal chemical compounds. Triatomic hydrogen. Neon and its parabolas. Attempts to separate its components. Failure of fractional distillation, success of diffusion experiments. Analogy to Soddy's radioactive isotopes.

"The Mass-spectrograph" was the subject of the lecture on Thursday afternoon. The following topics were considered:

Problem of increasing the accuracy of positive ray analysis. Methods of focussing the rays. Principle of the mass-spectrograph. Details of its construction and experimental technic. Standard lines. Lines of the first, second and higher orders. Mass-spectra of the chemical elements neon, chlorine, etc. Remarkable results with krypton, xenon and mercury. Mass-spectra of the alkali metals. Isotopes and the periodic law.

Dr. Joseph S. Ames, Director of the Physical Laboratory, Johns Hopkins University, Baltimore, M.F.I., presided.

The closing lecture of the series on "Isotopes and the Structure of the Atom" was given on Friday afternoon. The following topics were considered:

The whole number rule. Abnormality of hydrogen. Method of measuring masses of hydrogen and helium by "bracketing." The electrical structure of atoms, protons and electrons. The Rutherford atom and its later development

by Bohr and Langmuir. The spectra of isotopes. Their chemical identity and its probable explanation. Separation of isotopes. Possible methods. Work of Bronsted and Hevesy. Suggested explanation of the constancy of the composition of chemical elements and conjectures as to their evolution.

Dr. Arthur L. Day, Geophysical Laboratory, Washington, D. C., M.F.I., presided.

Physicists and Chemists were in attendance from all parts of the Eastern, Southern and Midwestern States and Canada.

A paper by Doctor Aston, giving a summary of these lectures, appears in this number of the Journal.

MEMBERSHIP NOTES.

ELECTION TO MEMBERSHIP.

(Stated Meeting, Board of Managers, April 12, 1922.)

LIFE MEMBERSHIP.

Mr. Joseph McClary Emerick, 1501 Commonwealth Building, Philadelphia, Pennsylvania.

RESIDENT MEMBERSHIP.

Mr. John Irwin Bright, Otis Building, Philadelphia, Pennsylvania.
Mr. J. Heron Crosman, Jr., The Bell Telephone Company of Pennsylvania, Philadelphia, Pennsylvania.
Mr. Frederic H. Garrigues, 6806 N. 11th Street, Philadelphia, Pennsylvania.
Mr. L. H. Kinnard, The Bell Telephone Company of Pennsylvania, Philadelphia, Pennsylvania.
Mr. Howard S. Levy, 1424 N. 15th Street, Philadelphia, Pennsylvania.

NON-RESIDENT MEMBERSHIP.

Dr. L. W. McKeehan, 463 West Street, New York City, New York.
Mr. Frederick J. Pearson, 25 E. Washington Street, Chicago, Illinois.

CHANGES OF ADDRESS.

Mr. E. G. Bashore, care of Dr. J. D. Bashore, Shippensburg, Pennsylvania.
Mr. A. W. K. Billings, Canadian and General Finance Company, Limited, Toronto, Canada.
Mr. J. V. Bostwick, St. Davids, Pennsylvania.
Dr. Frank K. Cameron, 46 Bransford Apartments, Salt Lake City, Utah.
Mr. Fred Denig, 87 Magnolia Avenue, Jersey City, New Jersey.
Mr. Kern Dodge, Morris Building, Philadelphia, Pennsylvania.
Mr. Byron E. Eldred, 30 Nassau Road, Great Neck, Long Island, New York.
Mr. C. E. Foster, 120 St. George's Road, Ardmore, Pennsylvania.
Mr. Geo. W. McClelland, 3112 Troost Avenue, Kansas City, Missouri.
Mr. Frederick C. Fearing, 2112 Delancey Place, Philadelphia, Pennsylvania.
Mr. Leon W. Nichols, Glenolden, Pennsylvania.

Mr. Joseph J. Rhoads, Miller Park, Franklin, Pennsylvania.
Mr. F. A. Seiberling, 41 East Mill Street, Akron, Ohio.
Mr. C. F. Sulzner, 236 S. W. 2nd Street, Miami, Florida.

NECROLOGY.

William Colwell Carnell was born in Philadelphia on June 11, 1869, and died on March 12, 1922. After the usual training in the public schools he entered the Central High School in February, 1885, from which he was graduated in February, 1889, with the degree of Bachelor of Arts. In the following year he became a student at Lehigh University and was one of the graduates of the class of 1894 in Analytical Chemistry. Immediately after graduation he entered the chemical laboratories of the Hill Steel Plant at Chicago, where he remained three years. The next four years he spent as chemist for the Nelson-Morris Company at the Chicago Stock Yards. From 1901 to 1914 he was connected with Charles Lennig and Company and the three following years he spent with the Harrison Paint Company. In 1917 he was engaged with the Rohm and Haas Company and in the following year he again became connected with the Charles Lennig Company. He was Vice-president of the latter company at the time of his death.

For several years he was instructor in Chemistry in the evening classes of Temple University.

He was a member of numerous clubs, the American Institute of Chemical Engineers, the American Chemical Society and the Society of Chemical Industry. His interest in the Institute began when a minor and continued throughout his entire life. He became a member of The Franklin Institute on July 11, 1913, and was elected to membership in the Committee on Science and the Arts in January, 1916.

Henry Hess was born at Darmstadt, Germany, in 1862, and died in Atlantic City, New Jersey, on March 24, 1922.

He was educated in private schools in New York City and then returned to Germany for the purpose of entering one of its high schools. During his career as a designer and mechanical engineer he was connected with the Pond Machine Tool Company, Watervliet Arsenal, Niles Tool Works, and the Bureau of Construction and Repair of the United States Navy. He was consulting engineer and managing director of the German Niles Tool Works at Berlin and founder and president of the Hess-Bright Manufacturing Company, Hess-Steel Company, and Hess-Ives Company.

He was a member of the American Society of Mechanical Engineers, the Society of Automobile Engineers, the American Institute of Mining Engineers, American and International Societies for Testing Materials, the Institute of Automobile Engineers, the Engineers' Club of Philadelphia, the Society of German Engineers and a number of clubs. He became a member of The Franklin Institute on October 8, 1904.

LIBRARY NOTES.

PURCHASES.

American Annual of Photography, 1922. 1921.

Aston, F. W.—Isotopes. 1922.

Bird, J. Malcolm [ed. and comp.].—Einstein's Theories of Relativity and Gravitation. 1921.

Bugbee, Edward E.—Text-book of Fire Assaying. 1922.

Dana, Edward S.—Text-book of Mineralogy, Ed. 3. 1922.

Dumesny, P., and Noyer, J.—Wood Products: Distillates and Extracts. 1921.

Engler, C., and H. v. Hoefer.—Das Erdöl. 1919.

Grabau, Amadeus W.—Comprehensive Geology, 2 vols. 1920-21.

Grard, C.—Aluminium and Its Alloys. 1922.

Hatschek, Emil.—Introduction to the Physics and Chemistry of Colloids, Ed. 4. 1922.

Herzfeld, J.—Technical Testing of Yarns and Textile Fabrics, Ed. 3. 1920.

Index Generalis.—Annuaire Générale des Universités. 1921.

Jones, Charles L.—Service Station Management. 1922.

Lane, F. Van Z.—Motor Truck Transportation. 1921.

Leggett, Bernard.—Wireless Telegraphy. 1921.

Mellor, J. W.—Comprehensive Treatise on Inorganic and Theoretical Chemistry, 2 vols. 1922.

Mineral Industry, 1920. 1921.

Morrell, R. S., and Waele, A. de.—Rubber, Resins, Paints and Varnishes. 1920.

Munby, Alan E.—Laboratories, Their Planning and Fittings. 1921.

Newland, H. O.—Coconuts, Kernals, Cacao. 1919.

Poiree, J.—Précis d'Arithmétique. 1921.

Prout, H. G.—Life of George Westinghouse. 1922.

Sabine, Wallace C.—Collected Papers on Acoustics. 1922.

Salter, M. de C. S.—Rainfall of the British Isles. 1921.

Sammlung chemischer und chemisch-technischer Vorträge. 26 vols. 1896-1919.

Sherman, H. C., and Smith, C. L.—Vitamins. 1922.

Singer, Charles.—Studies in the History and Method of Science. 1921.

Society of Chemical Industry. Chemical Engineering Group, Proceedings 1919. 1919.

Taggert, Arthur F.—Manual of Flotation Processes. 1921.

Thomson, Sir J. J.—Rays of Positive Electricity. Ed. 2. 1921.

Young, Sidney.—Distillation, Principles and Processes. 1922.

Yule, G. Udny.—Theory of Statistics, Ed. 5. 1919.

GIFTS.

Agricultural and Mechanical College of Texas, Bulletins 22 and 24 of Bituminous Pavement Investigations. College Station, Texas, 1921. (From the College.)

Allen, Edgar, and Company, Limited, Catalogue of Tool Steels. Sheffield, England, 1921. (From the Company.)

Alpha Portland Cement Company, Alpha Aids No. 29. Easton, Pennsylvania, 1921. (From the Company.)

American Broach and Machine Company, Hand-Book. Ann Arbor, Michigan, 1921. (From the Company.)

Ashton Valve Company, Ashton Pop Safety and Relief Valves. Boston, Massachusetts, 1921. (From the Company.)

Bangor Public Library, Annual Reports for 1921. Bangor, Maine, 1921. (From the Library.)

Barber-Greene Company, Results on Road Jobs. Philadelphia, Pennsylvania, no date. (From the Company.)

Bay City Dredge Works, Circular 10 of Excavators. Bay City, Michigan, 1921. (From the Works.)

Belke Perfect Tank Filter Company, Booklet of Good Plating. Chicago, Illinois, no date. (From the Company.)

Bergius Launch and Engine Company, Limited, Silent Marine Engine and Kelvin Marine Engines. Glasgow, Scotland, 1921. (From the Company.)

Brown and Sharpe Manufacturing Company, Automatic Milling Machine. Providence, Rhode Island, 1921. (From the Company.)

Carnegie Institution of Washington, Year Book No. 20, 1921. Washington, District of Columbia, 1921. (From the Institution.)

Cement Gun Construction Company, Gunite Book No. 7. Chicago, Illinois, 1922. (From the Company.)

Cincinnati Manufacturing Company, Catalogue No. 47, Bronze, Iron and Wire Work. Cincinnati, Ohio, 1921. (From the Company.)

Cincinnati Milling Machine Company, Cincinnati Milling Machines. Cincinnati, Ohio, 1921. (From the Company.)

Clarkson College of Technology, Commencement and Alumni Numbers for 1921. Potsdam, New York, 1921. (From the College.)

Cleveland Hardware Company, Catalogue 15-B of Truck Body Forgings. Cleveland, Ohio, no date. (From the Company.)

Cook, A. D., Incorporated, Catalogue 16 of Brass Tubes. Lawrenceburg, Indiana, 1921. (From the Company.)

Copper Clad Steel Company, Catalogue of Copper Clad Steel Wire. Rankin, Pennsylvania, 1918. (From the Company.)

Cutter Company, Booklet on U-Re-Lite. Philadelphia, Pennsylvania, 1921. (From the Company.)

Danzig Technical High School, Twenty Publications issued during the years 1919 and 1920. Danzig, Germany, 1919 and 1920. (From the High School.)

Dean Brothers, Durable Duplex Pumps. Indianapolis, Indiana, 1921. (From the Company.)

Delta Star Electric Company, Bulletin No. 37. Chicago, Illinois, 1922. (From the Company.)

Deschanel Engineering Corporation, Deschanel Cableway Bulletin. New York City, New York, 1922. (From the Corporation.)

Detroit Stoker Company, Detroit " V " Type Stoker. Detroit, Michigan, no date. (From the Company.)

de Zeng, Henry L., The Phoroptor. Camden, New Jersey, 1922. (From the Author.)

Direct Separator Company, Booklets D-21 and S-21 of Steam and Oil Separators. Syracuse, New York, 1921. (From the Company.)

Dixon, Joseph, Crucible Company, Colors and Specifications, Notable Buildings. Jersey City, New Jersey, no date. (From the Company.)

Edge Moor Iron Company, General Catalogue of Edge Moor Water Tube Boilers. Edge Moor, Delaware, 1921. (From the Company.)

Ehret Roofing and Manufacturing Company, Catalogue on Roofing and Concrete Floors. Philadelphia, Pennsylvania, no date. (From the Company.)

Ellison, George, Bulletin Catalogue of Switches and Motor Controllers. Perry Barr, Birmingham, England, no date. (From the Company.)

Eureka Pneumatic Spray Company, Incorporated, Catalogue of Sprays. New York City, New York, 1921. (From the Company.)

Evans, W. L., Evans Vanishing Doors. Washington, Indiana, 1921. (From Mr. Evans.)

Fafnir Bearing Company, Catalogue 21. New Britain, Connecticut, 1921. (From the Company.)

Fairmont Gas Engine and Railway Motor Car Company, The Story of Fairmont. Fairmont, Minnesota, 1921. (From the Company.)

Fitchburg Grinding Machine Company, Bulletin Catalogue of Grinding Machines. Fitchburg, Massachusetts, no date. (From the Company.)

Foote Company, Incorporated, Catalogue 8 of Multifoote Paver. Nunda, New York, no date. (From the Company.)

General Radio Company, Bulletins Nos. 103, 104 and 910. Cambridge, Massachusetts, 1922. (From the Company.)

Handstock, Limited, Cyc-arc Automatic Welder. Wokingham, Berks, England, 1921. (From the Company.)

Hartford Steam Boiler Inspection and Insurance Company, The Locomotive, vol. xxxiii. Hartford, Connecticut, 1920. (From the Company.)

Harvard University, Catalogue 1921–1922. Cambridge, Massachusetts, 1921. (From the University.)

Haverford College, Catalogue 1921–1922. Haverford, Pennsylvania, 1921. (From the College.)

Head, Wrightson and Company, Bulletins of Jaw Crushers, Headgears, Coal Screening, Marcus Screens and Conveyors, " Nota Nos " Washers, Grinding Pans, Stamp Mills, Coal Shippers and Hoists, Rotary Dryer, Lowden Patent Dryer, Colorado Impact Screen, Akins Classifier, Tube Mills, Rod Mills, Ball Mills, Crushing Rolls and Roasting Furnaces. Thornaby-on-Tees, England, 1921. (From the Company.)

Hingley, N., and Sons, Limited, Forgings, Drop Forgings and General Smith's Work. Dudley, England, no date. (From the Company.)

Howe Chain Company, Trucking System Catalogue 4 and Chains for Elevating Catalogue 121. Muskegon, Michigan, 1921. (From the Company.)

Hunt, Robert W., and Company, Specifications for Track Material. Chicago, Illinois, 1921. (From the Company.)

Hydraulic Press Manufacturing Company, Catalogue 43-B of Valves and Fittings. Mount Gilead, Ohio, 1921. (From the Company.)

Ideal Electric and Manufacturing Company, Bulletins 101, 105 and 106, Motor-generator Sets and Bulletin 107, Electro-plating Apparatus. Mansfield, Ohio, no date. (From the Company.)

Imperial Earthquake Investigation Committee. Seismological Notes No. 1. Tokyo, Japan, 1921. (From the Committee.)

Imperial Light, Limited, Catalogue c6 of Plants for Acetylene Installations. London, England, no date. (From the Company.)

India Government Observatory, Magnetical, Meteorological, and Seismographic Observations. Bombay, India, 1921. (From the Observatory.)

India Posts and Telegraphs, Annual Report 1920–1921. Delhi, India, 1921. (From the Director General.)

Industrial Air Engineering Company, Bulletins 7, 8, 9 and 11. Cleveland, Ohio, no date. (From the Company.)

Institute of Metals, Journal No. 2, vol. xxvi, 1921. London, England, 1921. (From the Institute.)

Institution of Civil Engineers, Minutes of Proceedings, vol. ccx. London, England, 1921. (From the Institution.)

Institution of Mining and Metallurgy, Transactions, Twenty-ninth Session, 1919–1920. London, England, 1920. (From the Institution.)

Iron and Steel Institute, Journal, vol. civ, 1921. London, England, 1921. (From the Institute.)

Jaeger Machine Company, Jaeger Mixers. Columbus, Ohio, no date. (From the Company.)

Jardine, John, Limited, Power Transmission Appliances. Nottingham, England, 1921. (From the Company.)

Kay Manufacturing Company, Circular 1922 of Free Floating Couplings. Norwalk, Connecticut, 1922. (From the Company.)

Kentucky, Sixth Geological Survey, Administrative Report. Frankfort, Kentucky, 1921. (From the Director.)

Kostevitch, M., " T.N.B. and T.N.T." and High Explosive and Smokeless Powder Testing Electrical Apparatus. London, England, no date. (From the Author.)

Kyle, George W., and Company, Incorporated, Illustrated Catalogue of Polishing and Electroplating Plants. New York City, New York, 1921. (From the Company.)

Landis Machine Company, Landis Die Heads and Machines. Waynesboro, Pennsylvania, 1921. (From the Company.)

Leeds and Northrup Company, Bulletin 715. Philadelphia, Pennsylvania, 1922. (From the Company.)

Library of Congress, Report for 1921. Washington, District of Columbia, 1921. (From the Library.)

London Steam Turbine Company, Bulletin 11 of Steam Turbines. Troy, New York, 1922. (From the Company.)

Luke and Spencer, Limited, Abrasive Wheels. Broadheath, England, 1920. (From the Company.)

Lynchburg Foundry Company, Cast Iron Pipe Fittings. Lynchburg, Virginia, 1922. (From the Company.)

McCormick, J. S., Company, Foundry Equipment List No. 70. Pittsburgh, Pennsylvania, no date. (From the Company.)

McKee, Garnet W., Heat Treatment of Steel in Gas Furnaces. Rockford, Illinois, 1918. (From the Eclipse Fuel Engineering Company.)

Martin Brothers, Limited, Power Transmitting Machinery. Manchester, England, 1921. (From the Company.)

Matthews Engineering Company. Booklet, Full Automatic Lighting. Sandusky, Ohio, 1921. (From the Company.)

Mesta Machine Company, Una-flow Engines and Gas-blowing Engines. Pittsburgh, Pennsylvania, 1921. (From the Company.)

Metropolitan-Vickers Electrical Company, Limited, Individual Drive and Control of Machine Tools. Manchester, England, no date. (From the Company.)

Michigan Public Domain Commission, Biennial Report. Lansing, Michigan, 1921. (From the Commission.)

Milliken Brothers Manufacturing Company, Steel Radio Towers for Broadcasting and Steel Transmission Towers. New York City, New York, 1921. (From the Company.)

Mississippi State Geological Survey, Bulletin 17 of Plants of Mississippi. Jackson, Mississippi, 1921. (From the Director.)

Mitchell Conveyor and Transporter Company, Limited, Locomotive Coal and Ash Handling Plants. London, England, no date. (From the Company.)

Mount Holyoke College, Catalogue, 1921–1922. South Hadley, Massachusetts, 1921. (From the College.)

Mumford, John Kimberly, Outspinning the Spider. New York City, New York, no date. (From the Roebling Wire Rope Company.)

Nalder Brothers and Thompson, Limited, Catalogue of Portable Instruments. London, England, no date. (From the Company.)

National Carbon Company, Incorporated, The Carbon Electrode. New York City, New York, 1922. (From the Company.)

National Electric Light Association, Proceedings of Forty-fourth Convention, vols. i and ii. New York City, New York, 1921. (From the Association.)

National Injector and Ejector Company, Limited, Catalogue of Steam Appliances. Manchester, England, no date. (From the Company.)

New Hampshire Public Service Commission, Annual and Statistical Report for 1920. Concord, New Hampshire, 1921. (From the Commissioners.)

New Jersey Asbestos Company, Booklet of Engine Packings. Camden, New Jersey, 1921. (From the Company.)

Newman, Andrew, Company, High Speed and Carbon Tool Steels of J. H. Andrew and Company. New York City, New York, no date. (From the Company.)

New York General Society of Mechanics and Tradesmen, 136th Annual Report. New York City, New York, 1922. (From the Society.)

New York State Library, 101st Annual Report, 1918. Albany, New York, 1920. (From the Library.)

New York State Museum, Seventy-second Report, 1918. Albany, New York, 1920. (From the State University.)

New York Water Power Commission, First Annual Report. Albany, New York, 1921. (From the Commissioners.)

Niagara Machine and Tool Works, Presses. Buffalo, New York, 1921. (From the Works.)

Niebling, F. W., and Company, Catalogue No. 4 of Ice and Refrigerating Machinery. Cincinnati, Ohio, no date. (From the Company.)

Normand, Augustin, Les Moteurs Diesel. Le Havre, France, 1919. (From M. Normand.)

Norris, Henty and Gardners, Limited, Index Catalogue of Gardner Engines. London, England, 1921. (From the Company.)

Norske Ingeniorforenings, N.I.F.'s Love, Optagelsesregler, Etiske Regler. Kristiania, Norway, 1921. (From the Society.)

Northern Central Railway Company, Sixty-seventh Annual Report for the Year 1921. Philadelphia, Pennsylvania, 1921. (From the Company.)

Norton Company, How to Order Grinding Wheels, Grinding Wheels Selection, Grinding Machines and Metal Polishing. Worcester, Massachusetts, 1921. (From the Company.)

Novo Engine Company, Novo-Power. Lansing, Michigan, 1922. (From the Company.)

Ohio Wesleyan University, 1922 Catalogue. Delaware, Ohio, 1921. (From the University.)

Oilgear Company, Hydraulic Power Transmissions. Milwaukee, Wisconsin, 1921. (From the Company.)

Ontario Department of Public Highways, Annual Report for 1919. Toronto, Canada, 1921. (From the Minister of Public Works and Highways.)

Ontario Hydro-electric Power Commission, Thirteenth Annual Report. Toronto, Canada, 1921. (From the Commissioners.)

Oregon Agricultural College, Bulletins 186 and 187. Corvallis, Oregon, 1922. (From the College.)

Ottawa Advisory Research Council, Reports 8, 9 and 10 of 1921 and Report 10 of 1922. Ottawa, Canada. (From the Council.)

Pangborn Corporation, Bulletins 704A and 706. Hagerstown, Maryland, 1921. (From the Corporation.)

Pardee Steel Corporation, Booklet of Open Hearth Steel. Perth Amboy, New Jersey, 1921. (From the Corporation.)

Pawling and Harnischfeger Company, Bulletin 4F of Horizontal Boring, Drilling and Milling Machines. Milwaukee, Wisconsin, 1921. (From the Company.)

Pease, C. F., Company, Booklet of Blue Printing Equipment. Chicago, Illinois, 1920. (From the Company.)

Pennsylvania Department of Labor and Industry, Bulletin 4 of vol. viii. Harrisburg, Pennsylvania, 1921. (From the Department.)

Pennsylvania General Assembly, Laws Passed at the Session of 1921. Harrisburg, Pennsylvania, 1921. (From the Assembly.)

Pennsylvania Workmen's Compensation Bureau, Rules and Decisions, vol. iii, 1920. Harrisburg, Pennsylvania, 1921. (From the Bureau.)

Peter Brotherhood, Limited, Air and Gas Compressors. London, England, no date. (From the Company.)

Philadelphia Rapid Transit Company, Annual Report to the Stockholders. Philadelphia, Pennsylvania, 1921. (From the Company.)

University of Illinois, Soil Report No. 20. Urbana, Illinois, 1921. (From the University.)

University of Toronto, Calendar 1921–1922 and Final Examination Papers, 1921. Toronto, Canada, 1921. (From the University.)

University of Virginia, Catalogue 1921–1922. Charlottesville, Virginia, 1922. (From the University.)

Vanderbilt University, Register, 1921–1922, and Announcement, 1922–1923. Nashville, Tennessee, 1922. (From the University.)

Vickers-Petters, Limited, Pamphlet of Crude, Residual and Refined Oils. Ipswich, England, no date. (From the Company.)

Visco Engineering Company, Limited, Visco Air Filters. London, England, no date. (From the Company.)

Vulcan Iron Works, Incorporated, Buckets. Jersey City, New Jersey, 1921. (From the Works.)

Wagner Electric Manufacturing Company, Bulletin 129. St. Louis, Missouri, 1922. (From the Company.)

Washington Department of Public Works, First Annual Report, 1921. Olympia, Washington, 1921. (From the Department.)

Washington University, University Record, February, 1922. St. Louis, Missouri, 1922. (From the University.)

Western Reserve University, Catalogue, 1921–1922. Cleveland, Ohio, 1921. (From the University.)

Williams, G. H., Company, Practical Plant Layouts for Handling Concrete Materials. Erie, Pennsylvania, 1922. (From the Company.)

Williams and Williams, Limited, Reliance Metal Windows. Chester, England, 1921. (From the Company.)

BOOK NOTICES.

METRIC SYSTEM FOR ENGINEERS, by Charles B. Clapham, Hons. B. Sc. Eng. 178 pages and index, small 8vo. New York, E.P. Dutton and Company, 1922. Price $6.00 net.

The author tells us that the object of this book is an explanation of the metric system from the technical point of view, but he does not enter positively into the question of the compulsory adoption of it by any nation. His views are, of course, entirely directed toward the agitation on the subject in Great Britain. It is stated that the metric system is now regularly taught in British schools, but it is still regarded by many as an alien topic, and he says, further, that even those who use the units in the drafting room or workshop are rarely confident in calculating with them. This language sounds a little strange to American readers, who are so familiar with the decimal units of our currency, but it appears to be true that the curious arithmetical relations of pounds, shillings and pence have developed in the English a lack of facility with decimal calculations in some ways. Herbert Spencer, who, as is well known, was a bitter opponent of the metric system and even pursues it after death, for he left an endowment to pay for literature

opposing it, remarks in one of his attacks that a certain British accountant had told him that he had just finished a very elaborate review of a monetary transaction in English currency, and that he was very glad it was not in francs. Yet it is a curious fact, that may be mentioned in this connection, that Spencer looks with some favor upon the compulsory adoption of a duodecimal system which he declares would be much more convenient than the decimal one. He is right on this point. A base of twice 6 would make a more convenient system of calculation than the present base of twice 5. Discussions of the latter type, however, may be regarded as purely academic. It is an interesting fact that of all the great nations of the world, the English speaking ones are alone in direct antagonism to the metric system. It is not the decimal character alone that is the advantage, for after all, as regards measures length and surface, we can meet the problem by dividing the inch into tenths, hundredths and thousandths, which is as convenient as dividing the centimetre into similar fractions. A great value that the introduction of the metric system has, and the one which has made it especially popular among chemists and physicists, is its simplification of the data in weights and volumes. The simple relation of the gram to the litre, of the centimetre to the litre and the ease with which questions of percentage of standard solutions of different strengths may be calculated, has rendered this system an indispensable method in the laboratory and for many years all leading British and American chemists have entirely relied upon it. Apart from the simplification of these relations the fact that by means of the system we can get rid of the confusion of the old units is no small gain. An ounce, for example, may be a troy ounce, an avoirdupois ounce or a fluid ounce. When an English chemist speaks of a gallon, he means the imperial gallon of ten avoirdupois pounds. When an American chemist speaks of a gallon he means the United States or wine gallon (if permissible to allude to wine nowadays) of 8.33 pounds and the serious confusions that may thus arise are easily seen.

Turning to the work itself under consideration, it is an elaborate collection of data covering the whole subject of the conversion to and fro between the metric system and the older, or so-called, British system. Fourteen pages are devoted to a brief survey of the controversy which, as well known, has been extremely bitter in both Great Britain and America. The complexity of the older system is presented and it is rather interesting to note in the brief account of the history of the metric system that a decimal basis for a system of weights and measures was first proposed by James Watt in 1783, and that the decimal basis of United States currency, which has been of such immense economy to the American people, is due to Thomas Jefferson. It is, of course, known to all who are interested in this field that the original intention of the metric system was to obtain a natural absolute basis, the one-forty millionth of the earth's meridian. It is now known that the arc of the earth's surface which was measured for this purpose, was not correctly determined, and consequently the standard metre is an arbitrary quantity. A list of industries in England in which the output is wholly metric is given, and is certainly encouraging. It is impossible here to review to any extent the chapter on the controversy, but the general opinion of the author seems to be that most of the objections are not as serious as believed by those who

urged them. Taken all in all, the book contains a vast amount of carefully selected and arranged details, which will undoubtedly aid very materially those who desire to employ the system and are not familiar with the general principles, or do not care to acquaint themselves with these principles, but wish to be able to pass quickly from one unit in a given case to its equivalent in another.

The book is well printed, the many tables are clear and there are numerous illustrations. Taken as a whole it is an argument in favor of the general adoption of the metric system.

<div align="right">HENRY LEFFMANN.</div>

GAS CHEMISTS HANDBOOK, compiled by the Chemical Committee of the Technical Section of the American Gas Association. Second edition, 586 pages and index, 113 illustrations, numerous tables, 8vo. New York, The American Gas Association. Price, $6.00 net.

The production of illuminating gas is important not only for the product itself, which affords a very convenient method of lighting and heating, especially the latter, but also for the by-products which have been of late years, as is well known, the source of a great variety of important substances. The present work is devoted to the analytical methods required of the gas engineer and not to the technology or business problems. These latter, of course, are very important features of the industry, but the chemist is not directly concerned with either of them. The book is an extensive presentation of the methods of analysis of all the materials used and produced in the manufacture of gas. It begins with a chapter on raw materials including coal, coke, and oil and the substances used for the purification of the products.

The analytical procedures in regard to the products, both the gas itself and the other materials, are then considered in a chapter of over 200 pages. The examination of tar from both water- and coal-gas receive full attention. Two of the by-products that are now increasing in importance in consequence of the probable early exhaustion of the great supply of combined nitrogen from Chili, namely, ammonia and cyanogen, are especially studied in the impurities in the gas. Some which are of the most serious nature, and not always easy to remove, are then taken up, including especially hydrogen sulphide and other sulphur compounds, which latter include carbon disulphide.

An interesting impurity in the gas and one that would have seemed impossible in the early days of gas engineering is iron carbonyl. This volatile compound of iron is formed in the high temperature of the retort and is a serious impurity under certain conditions. It appears that the process for its determination, which is here given, is strongly recommended, although not in general use. It essentially depends upon the oxidation of the product by nitric acid or bromine. The compound is present in minute quantities, as a rule, which renders it necessary to treat rather large volumes of gas in order to obtain satisfactory determinations.

The complexity of the gas industry is well illustrated by the extension and variety of the last chapter which discusses the accessory materials used in the construction and operation of the works. Among these water receives very careful consideration. The methods employed are those endorsed by the American Public Health Association and hence will require no particular

criticism. It is to be noted, however, that these methods include the test of hardness by the use of soap solution. It would seem that in any well-equipped laboratory the calcium and magnesium of a given sample could be very conveniently determined by the ordinary process of analysis and thus the somewhat uncertain method of soap solution be left to one side.

The other substances that are treated are paint and paint materials, lubricants, solder, bearing metals, brass and bronze, pipe deposits, refractory materials, cement and lime and ferrous metals, under which last term is included the analysis of steels, pig and cast iron. The methods used for these purposes are those of the American Society for Testing Materials. Numerous tables are given for conversions of various kinds and for analytical calculations. A fairly good index closes the volume.

The book represents an up-to-date collection of analytical methods involved in the operation of a gas plant. Its compilers are men who have worked in these lines for years and are thoroughly familiar with the requirements of the industry and it is a valuable addition to the literature of chemical engineering. It is a well-printed and well-illustrated volume.

<div align="right">Henry Leffmann.</div>

The Forest Products Laboratory. A Decennial Record. Published by the Decennial Committee, Edward F. Weiss, Chairman. 8vo, 196 pages and many illustrations. Madison, Wisconsin. Price, $1.75.

This laboratory for studying the characters and utilization of forest products was established at the University of Wisconsin in 1910, and it has been deemed appropriate to celebrate the decennial anniversary by the publication of a volume summarizing the work done. The operation of the laboratory is carried out by members of the Staff of the Forest Service of the Department of Agriculture. The book is a handsomely printed and well-illustrated volume, and is an opportune contribution to one of the most important fields of national industry.

Undoubtedly, the preservations of our forests and the utilization as far as possible of all the products, is a matter worthy of most careful and energetic research. The text of the work is introduced by a chapter showing the relation of wood to civilization. The contrast between countries that maintain appreciable amounts of forest and those that allow unrestricted devastation, is alone sufficient to show the value of forest conservation. Such conservation does not in any way limit the reasonable use of the forest. The work of the forest laboratory is very extensive, one of the most important being the study of preservatives. Much of the volume is, as might be expected, taken up with personal matters, but illustrations of the various appliances of the laboratory are inserted and show the wide range of work that can be carried on. It is a " forest products " laboratory, not a centre of forestry management, so that questions of conservation of forests as such, fire prevention, systematized culling and other matters that are involved in the national and state forestry services are not presented. The work will be especially valuable in showing how wood that was formerly considered worthless can be applied to useful purposes.

<div align="right">Henry Leffmann.</div>

Zirconium and Its Compounds. By Francis P. Venable. 148 pages, bibliog-
    raphy and index, 8vo. The Chemical Catalog Company, New York.
    Price, $2.50 net.

This is another volume of the A.C.S. monograph series. Devoted entirely
to the chemistry of one element, and that element commonly regarded as among
the rarer and less important substances, the volume shows the high development
of specialism in the science, and the manner in which research is bringing
into prominence elements hitherto deemed worthy of merely a line or two in
our standard text-books. At present, zirconium can scarcely be considered a
rare element, its compounds being found in appreciable amount in many parts
of the world, yet it is in far less supply than such substances as aluminum and
silicon. It was identified as a distinct element by Klaproth in 1789. Separation
of the metal in the pure condition is difficult on account of its high affinity for
oxygen and the presence of other somewhat analogous elements in its ores.
It is classified in the fourth group, which begins with carbon, hence the typical
oxide is ZrO_2 and the chloride $ZrCl_4$. It, however, shows some analogies to
uranium on the one hand and to bismuth and antimony on the other. Thus it
tends to form salts in which oxygen partly takes the place of the ordinary
acid radicles, which is noted in connection with uranium, and many of its salts
are promptly decomposed by water with the formation of oxy- or hydroxy
salts as occurs with bismuth and antimony. One would be inclined to expect
such anomalies to occur rather with elements of high atomic weights, but the
atomic weight of zirconium is about 91, the highest figure being that found
by Venable and Bell in 1917, 91.76. This figure has not been accepted by the
International Committee, which gives 90.6.

Many uses of zirconium compounds are mentioned in the book, but it seems
that in each field the use is rather limited. The high melting point of the
oxide, and its permanence in the air led to its being recommended as a substi-
tute for lime in the oxyhydrogen light. Robert Hare, in 1820, first observed
the brilliancy of the light emitted by it. In 1868, du Motay, who gave a good
deal of attention to the improvement of street-lighting in Paris, used it in light-
ing the Tuileries. Welsbach made early use of zirconia in his mantles, but the
thoria-ceria mixture has taken its place. Considerable application has been
made of the high melting point of zirconia in the manufacture of refractories.
Alloys of zirconium with iron seem to have some valuable properties.

Professor Venable has collected in this book an immense amount of infor-
mation, set forth in clear, vivid language, and has practically combed the
literature clean for the data. He has not overlooked the comparatively
recently noted interesting fact that the hypophosphite is sensitive to light. An
extended bibliography, arranged chronologically, is appended. It must be
noted that, while the other publications of this series use the spelling " sulfide,"
" sulfate," etc., the present work has gone back to older spelling. Perhaps
this has been an oversight; perhaps the author has insisted on the forms, but
in any event it is to be regretted that a retrograde step has been taken.

The book maintains the standard already reached by this excellent and
valuable series.

                                                    Henry Leffmann.

NATIONAL ADVISORY COMMITTEE FOR AERONAUTICS. Technical Note No. 93. The Background of Detonation. By Stanwood W. Sparrow, Automotive Power Plants Section, Bureau of Standards. 17 pages, quarto. Washington, Committee, April, 1922.

The tendency of a fuel to detonate often renders it unsuitable for use in high compression engines. Detonation appears to be closely related to the explosion pressure and this depends upon the temperature and pressure of the charge before combustion. This paper discusses the influence upon explosion pressures and hence upon detonation of changes in compression ratio, spark advance, compression pressure and degree of scavenging. Consideration is given to the loss in power entailed by various methods of eliminating detonation. Preignition is shown to be another obstacle to the use of high compression ratios and its influence is compared with that of detonation.

Report No. 134, Performance of Maybach 300-Horsepower Airplane Engine. By S. W. Sparrow. 11 pages, illustrations, quarto. Washington, Government Printing Office, 1922.

This report deals with the results of a test made upon a Maybach engine in the altitude chamber of the Bureau of Standards, where controlled conditions of temperature and pressure can be made to simulate those of the desired altitude.

The results of this test lead to the following conclusions: From the standpoint of thermal efficiency the full-load performance of the engine is excellent at densities corresponding to altitudes up to and including 15,000 feet. The brake mean effective pressure is rather low, even at wide-open throttle. This tends to give a high weight per horsepower, inasmuch as the weight of many engine parts is governed by the size rather than the power of the engine. At part load the thermal efficiency of the engine is low. Judged on a basis of performance the engine's chief claim to interest would appear to lie in the carburettor design, which is largely responsible for the excellent full-load efficiency and for its poor part load efficiency.

Report No. 135, Performance or B. M. W. 185-Horsepower Airplane Engine. By S. W. Sparrow. 10 pages, illustrations, quarto. Washington, Government Printing Office, 1922.

This pamphlet presents the results of a test made upon a B. M. W. engine in the altitude chamber of the Bureau of Standards.

A remarkably low value of fuel consumption—0.41 pound per b.h.p. hour— is obtained at 1200 r.p.m. at an air density of 0.064 pounds per cubic foot and a brake thermal efficiency of 33 per cent. and an indicated efficiency of 37 per cent. at the above speed and density. In spite of the fact that the carburettor adjustment does not permit the air-fuel ratio of maximum economy to be obtained at air densities lower than 0.064, the economy is superior to most engines tested thus far, even at a density (0.03) corresponding to an altitude of 25,000 feet.

The brake mean effective pressure even at full throttle is rather low. Since the weight of much of the engine is governed more by its piston displacement than by the power developed, a decreased mean effective pressure usually necessitates increased weight per horsepower. The altitude performance

of this engine is, in general, excellent, and its low fuel consumption is the outstanding feature of merit.

Report No. 138, The Drag of C Class Airship Hull with Varying Length of Cylindrical Midships. By A. F. Zahm, R. H. Smith and G. C. Hill. 10 pages, illustrations, plates, quarto. Washington, Government Printing Office, 1921.

A model of the C class airship hull, when severed at its major section and provided with a cylindric mid-body of variable length, had its air resistance increased about in proportion to the length of the mid-body up to three diameters, and in about the manner to be expected from the increase of skin friction on this variable length. For greater length the drag increased less and less rapidly.

As usual for such models, the drag for any fixed length, at 20 to 60 miles an hour, is accurately of the parabolic form RaV^n, and hence the drag coefficient is of the hyperbolic form CaV^{n-2}, where n is slightly less than 2.

The variation of C with length is stated in the conclusion.

Report No. 139, Influence of Model Surface and Air-flow Texture on Resistance of Aerodynamic Bodies. By A. F. Zahm. 6 pages, quarto. Washington, Government Printing Office, 1922.

In this pamphlet is given an analysis of the resistance equation

$$D = \rho L^2 V^2 f\left(\frac{VL}{v}\right).$$

It is shown that the expression $f\left(\frac{VL}{v}\right)$ applies only to a special case of uniform air flow and model surface texture. In order to obtain comparable results under various conditions it is necessary to use a more general form of the resistance equation, such as

$$D = \rho L^2 V^2 f\left(\frac{VL}{v}, \frac{l}{L}, \frac{v}{V}, \frac{V}{a}, \frac{V^2}{Lg}\right)$$

in which $\frac{l}{L}$ is a measure of the model surface texture, and $\frac{v}{V}$ a measure of the air-flow texture. These two functions have particular application in the comparison of tests from different aerodynamical laboratories.

PUBLICATIONS RECEIVED.

Organic Chemistry or Chemistry of the Carbon Compounds, by Victor von Richter; edited by Prof. R. Anschütz and Dr. H. Meerwein. Volume II. chemistry of the carbocyclic compounds. Translated from the eleventh German edition by E. E. Fournier d'Albe. 760 pages, 8vo. Philadelphia, P. Blakiston's Son and Company, 1922.

Le Principe de Relativité et la Théorié de la Gravitation. Leçons professées en 1921 et 1922 a l'École Polytechnique et au Muséum d'Histoire Naturelle par M. Jean Becquerel. 342 pages, illustrations, 8vo. Paris, Gauthier-Villars et Cie., 1922. Price 25 francs.

Problèmes et Exercises d'Électricité Générale, par P. Janet. 253 pages, illustrations, 8vo. Paris, Gauthier-Villars et Cie., 1921.

Gas Chemists Handbook. Compiled by the Chemical Committee, Technical Section of the American Gas Association, March 1, 1922. Second edition, 608 pages, illustrations, plates, 8vo. New York, American Gas Association, no date. Price $6.00

Applied Calculus. An introductory text-book by F. F. P. Bisacre. 446 pages, illustrations, portraits, 12mo. New York, D. Van Nostrand Company, 1921. Price $3.75

Metric System for Engineers, by Charles B. Clapham. 181 pages, illustrations, 8vo. The Directly Useful Technical Series. New York, E. P. Dutton and Company, 1922. Price, $6.00.

Essai d'Optique sur la Gradation de la Lumière, par Pierre Bouguer. 131 pages, illustrations, 16mo. Paris, Gauthier-Villars et Cie., 1921.

The Forest Products Laboratory. A decennial record, 1910-1920. 196 pages, illustrations, portraits, quarto. Madison, Wisconsin, published by the Decennial Committee, 1921. Price $1.75

The Conservation of Natural Gas in Kentucky, by Willard Rouse Jillson, Director and State Geologist of the Kentucky Geological Survey. First edition. 152 pages, illustrations, maps, 12mo. Louisville, Kentucky, John P. Morton Company, 1922.

The Coal Industry in Kentucky. An historical sketch by Willard Rouse Jillson, Director and State Geologist of the Kentucky Geological Survey. 87 pages, illustrations, maps, 12mo. Frankfort, The State Journal Company, 1922.

National Advisory Committee for Aeronautics: Technical Notes, No. 25, Center of Pressure Coefficients for Aerofoils at High Speeds, by W. S. Diehl. 2 pages, plates, quarto. No. 87, Hydrostatic Test of an Airship Model by the Aeronautics Staff, Construction Department, Navy Yard. 15 pages, plates, photographs, quarto. No. 89, The Choice of the Speed of an Airship by Max M. Munk. 8 pages, plate, quarto. Technical Paper, No. 91, Notes on Propeller Design. The Energy Losses of the Propeller-I, by Max M. Munk. 10 pages, quarto. No. 92, Full Scale Determination of the Lift and Drag of a Seaplane by Max M. Munk. 5 pages, plate, quarto. Washington, Committee, 1922.

THE NATURE OF SPEECH AND ITS INTERPRETATION.*

BY

HARVEY FLETCHER, PH.D.

Research Laboratories of the American Telephone and Telegraph Company and Western Electric Company, Incorporated.

INTRODUCTION.

VARIOUS phases of this subject have received serious study by phoneticians, otologists, and physicists. On account of its universal interest, it has received attention from men in many branches of science. In spite of the large amount of time devoted to the subject, the progress in understanding its fundamental aspects has been rather slow. At the present time the physical properties which differentiate the various fundamental speech sounds are understood in only a very fragmentary way. Some very interesting and pains-taking work has been done on the physical analysis of vowel sounds, but the results to date are far from conclusive. Although several theories have been advanced to explain the way in which the ear interprets sound waves, they are still in the controversial stage.

The material which is presented here is the result of an in investigation which has been carried on in the Research Labora-

---

*Presented at a meeting of the Electrical Section of The Franklin Institute held Thursday, March 30, 1922.

tories of the American Telephone and Telegraph Company and Western Electric Company during the past few years.

To make a quantitative study of speech and hearing it is necessary to obtain the speech sounds at varying degrees of loudness and with definitely known amounts of distortion. The main reason why so few real results have been obtained in the investigation of speech sounds is due to the fact that it is extremely difficult to change the volume and distortion of these sounds by acoustic means. Due to recent developments in the electrical transmission of speech it is possible to produce the equivalent of these changes by electrical means. For this purpose a telephone system was constructed which reproduced speech with practically no distortion. It was arranged so that by means of distortionless attenuators the volume of reproduced speech could be varied through a very wide range, and so that by introducing various kinds of electrical apparatus the transmitted speech wave could be distorted in definitely known ways.

A method was developed for measuring quantitatively the ability of the ear to interpret the transmitted speech sounds under different conditions of distortion and loudness. By choosing these conditions properly, considerable information was gained concerning both speech and hearing. This indirect method of attack has a distinct advantage for engineering purposes, in that it measures directly the thing of most interest, namely, the degrading effect upon telephone conversation of introducing electrical distortion into the transmission circuit. However, the application of the results is not limited to this particular field.

METHOD OF MEASURING THE QUALITY OF SPEECH.

Briefly stated the method consists in pronouncing detached speech sounds into the transmitting end of the system and having observers write the sounds which they hear at the receiving end. The comparison of the called sounds with those observed shows the number and kind of errors which are made. The per cent. of the total sounds spoken which are correctly received is called the articulation of the system.

In order to understand the construction of the articulation lists and also to interpret the results of this investigation, I desire to give here a brief classification of the speech sounds, which is based upon the position of the various speech organs when the

sounds are being produced. It is shown in the accompanying table (Table I).

TABLE I.

Classification of the Speech Sounds.

Pure Vowels

w - y

ū (tool)   ē (team

   u (took)   i (tip)

    ō (tone)   ā (tape)
                                         e'r (term)
     ȯ (talk)   e (ten)

      o (ton)   ȧ (tap)

   ou   a (tar)   ī
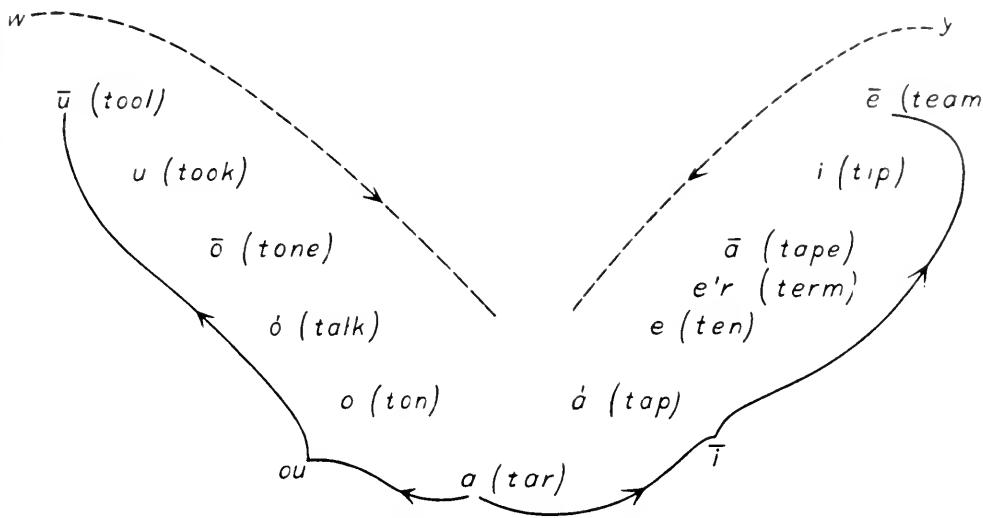
Combinational and Transitional Vowels
          w – y – ou – ĭ – h

Semi-vowels
          l – r

Stop Consonants

Voiced	Unvoiced	Nasalized	Formation of Stop
b	p	m	lip against lip
d	t	n	tongue against teeth
j	ch	–	tongue against hard palate
g	k	ng	tongue against soft palate

Fricative Consonants

Voiced	Unvoiced	Formation of Air Outlet
v	f	lip to teeth
z	s	teeth to teeth
th (then)	th (thin)	tongue to teeth
zh (azure)	sh	tongue to hard palate

The pure vowels are arranged in the vowel triangle, which is familiar to phoneticians. Starting with the sound ū the lips are rounded and there is formed a single resonant cavity in the front part of the mouth. Passing along the left side of the triangle from ū to a the mouth is gradually opened with the tongue lowered to form the successive vowels. Going along the right side of the

triangle from a to ē, the tongue is gradually raised to the front part of the mouth forming two resonant chambers in the mouth cavity. An infinite number of different shadings of these vowels may be produced by placing the mouth in the various intermediate positions, but the ones which are shown were chosen as being the most distinct.

The sounds w, y, ou, ī and h are classed as combinational and transitional vowels. As the mouth is placed in the position to say ū and then suddenly changed so as to form any other vowel in the triangle, the result obtained is signified in writing by placing the letter w before the vowel. In a similar way we get the effect usually designated by y if the position of the vowel suddenly changes from ē to any other vowel. An infinite variety of dipthongs can be formed by changing the position of the mouth necessary to form one vowel to that to form another without interrupting the voice. The most distinct and principal ones used in our language are formed by passing from the sound a to either extreme corner of the triangle and are known as ou and ī. When a vowel commences a syllable it is formed by suddenly opening the glottis, permitting the air, which has been held in the lungs, to escape into the mouth, which is formed for the proper vowel. If the glottis remains open and the vowel is started by the sudden contraction of the lungs, we have the effect which is represented in writing by placing an h before the vowel. The sounds l and r are called semi-vowels because the voice train is partially interrupted, although the sound can be continued. The stop and fricative consonants are classified in a manner which is familiar to phoneticians.

It will be noticed that the markings are not those used in the international phonetic alphabet which were entirely too complicated for practical use. Only the bar and accent stroke are used. These can be written quickly and with little chance of error.

In order to pronounce these speech sounds properly, they must be combined into syllables. For the purpose of this investigation they were combined into mono-syllables of the simple types consonant-vowel, vowel-consonant, and consonant-vowel-consonant.

To eliminate memory effects every possible combination of the sounds into these types of syllables was used unless there was a good reason for excluding it. The complete list contained 8700 syllables. For convenience of testing these syllables were divided

into groups of fifty. Each group contained the same kind and number of syllable forms and an equal number of each of the fundamental vowel and consonant sounds.

To illustrate the technique of articulation testing a sample list is given in Table II. In the first column the syllable is given in its phonetic form. A key-word showing how each syllable is pronounced is given in the second column. These syllables were writ-

TABLE II.
Speech-sound Testing List.   List No. 160.

	Speech-sound	Key-word		Speech-sound	Key-word
1	ha	ho(t)	26	gōb	go+b
2	hā	hay	27	shōl	shoal
3	wǎ	wa(g)	28	ros	rus(t)
4	wi	wi(th)	29	jod	ju(g)+d
5	vou	vow	30	bok	buck
6	ǎr	air	31	zīk	z+(d)ike
7	ez	e(bb)+z	32	bīch	buy+ch
8	ūsh	you+sh	33	kīth	ki(te)+th
9	an	on	34	gīt	gui(de)+t
10	id	(l)id	35	yif	y+if
11	jouv	jow(l)+v	36	sin	sin
12	moush	mou(nd)+sh	37	těrm	term
13	rour	r+our	38	měrl	m+earl
14	zūth	z+(s)oothe	39	pěrv	p+(n)erve
15	hūs	who+s	40	yēt	y+eat
16	chush	ch+(p)ush	41	bēl	b+eel
17	jum	j+(f)oo(t)+m	42	zef	ze(al)+f
18	thup	th+(s)'oo(t)+p	43	weng	whe(n)+ng
19	fuch	foo(t)+ch	44	kev	k+ev(er)
20	wǒng	wa(ll)+ng	45	hǎng	hang
21	chǒth	cha(lk)+th	46	pǎg	p+(r)ag
22	tǒj	ta(ll)+j	47	yǎs	y+ace
23	kǒg	k+aug(er)	48	dāp	d+ape
24	fōn	(tele)phone	49	yang	ya(cht)+ng
25	dōs	dose	50	lan	l+on

ten on cards which were shuffled each time before they were used, so that the order in which they were pronounced was entirely haphazard. One hundred and seventy-four similar lists were used in this work. In order to eliminate personal peculiarities, several callers and observers were used. In Table III are shown the results obtained by an observer when this list was transmitted over a system which eliminated all frequencies above 1250 cycles per second.

The correct word is written opposite all of the syllables which were recorded incorrectly. The errors for each of the fundamental

sounds were taken from this original sheet and recorded on an analysis sheet as shown on Table IV, for example it will be noticed that p was recorded as k 24.4 per cent., as p 45 per cent., and as t

TABLE III.

TRANSMISSION BRANCH
ARTICULATION TEST RECORDING SHEET

WORD ARTICULATION __40__ %

TITLE OF TEST __320311__

CONDITION TESTED __Low Pass Filter - 1250 ~__

DATE __2-7-20__   Attenuation = 5 napiers down   OBSERVER __M. A.__

TEST No. __11__   CALLER __H. E. D.__

LIST No. __160__

No.	OBSERVED	CALLED	ERRORS	No.	OBSERVED	CALLED	ERRORS
1	tan	te'rm	e'r-a / m-n	26	zip	thup	th-z / u-i
2	zit	git	g-z / ĭ-i	27	ko'd	to'j	t-k / j-d
3	wa	wa'	a'-a	28	tish	chush	ch-t / u-i
4	dāp	✓		29	yang	✓	
5	gōb	✓		30	zēt	zūth	ū-ē / th-t
6	yis	yif	f-s	31	ref	cos	o-e / s-f
7	māl	merl	e'r-ā	32	jum	✓	
8	thin	sin	s-th	33	jo'g	ko'g	k-j
9	zĭp	zĭk	k-p	34	jad	jod	o-a
10	jouv	✓		35	tŭth	hūs	h-t / s-th
11	yāt	yās	s-t	36	id	✓	
12	thou	vou	v-th	37	ha	✓	
13	bĭp	bĭch	ch-p	38	fōn	✓	
14	ha'ng	✓		39	ko'th	cho'th	ch-k
15	mĭs	moush	ou-ĭ / sh-s	40	rour	✓	
16	dāch	dōs	ō-ā / s-ch	41	an	✓	
17	kev	✓		42	bok	✓	
18	tig	pa'g	p-t / a'-i	43	yēt	✓	
19	kĭs	kĭth	th-s	44	o'r	a'r	a'-o'
20	hā	✓		45	yēth	ūsh	y inserted / ū-ē th / sh-ē th
21	weng	✓		46	wo'ng	✓	
22	dēl	bēl	b-d	47	kōv	pe'rv	p-k / e'r-ō
23	thich	fuch	f-th / u-i	48	zēt	zēf	f-t
24	wif	wi	f inserted	49	lan	✓	
25	ez	✓		50	shōl	✓	

22.2 per cent. of the times called. On the other hand the sound w was only recorded incorrectly 1 per cent. of the times called.

For this system the consonant articulation was 65.8 and the vowel articulation 83.4.

TABLE IV.

Summary Sheet — Average Errors above 5%
TRANSMISSION BRANCH
ARTICULATION TEST ANALYSIS SHEET

TITLE OF TEST _32031I_

CONDITION TESTED _Low Pass Filter — 1260~_   Average of

DATE _6–22–20_   Attenuation = 5 nepers down   OBSERVERS _8_

LIST Nos. _____   CALLERS _2_

TEST Nos. _____

SOUNDS CALLED	b	ch	d	f	g	h	j	k	l	m	n	ng	p	r	s	sh	th	t	v	w	y	z	Consonants	Insertions	% Error
b			10.3																				4.6		21.2
ch	7.8			11.0		4.9	3.5	8.7							3.2	7.3	4.3	24.7							56.6
d						3.5									24.0	11.7	19.0					3.9		55.2
f				6.2																					63.8
g		30.6				3.9							4.2												38.6
h				4.0																					13.5
j		15.3				3.3							3.8				33.7								29.9
k							10.1		3.7	2.9															48.0
l																									3.9
m								24.4						21.5	24.4	7.0	22.5					5.6		6.8
n		3.0												27.1	15.0		7.0				10.9			36.4
ng						3.4		19.6					6.2	21.1	18.3						3.1			5.6
p		3.4		0.4											10.7							15.1		55.0
r		7.3																							18.5
s																									44.9
sh																									53.2
th			6.2			4.2											9.3								70.7
t															4.8	8.8		7.9							42.4
v																									52.0
w																									1.0
y																									15.8
z																									39.9

No. of times each sound is called _____   Letter Articulation _72.2_

Total number of sounds called _____

Total number of errors _____   Word Articulation _41.2_

Consonant Articulation _66.8_

Summary Sheet — Average Errors above 2%
TRANSMISSION BRANCH
ARTICULATION TEST ANALYSIS SHEET

TITLE OF TEST _32031I_

CONDITION TESTED _Low Pass Filter — 1250~_   Average of

DATE _6–22–20_   Attenuation = 5 nepers down   OBSERVERS _8_

LIST Nos. _____   CALLERS _2_

TEST Nos. _____

No. of Times Called / Sounds called	a	a	á	e	e	è	ér	er	l	i	o	ó	ó	u	u	ou	% ERROR
a			10.2														15.1
a																	2.2
á	13.8								2.2			3.8					27.5
e		2.4	2.3	4.3						10.0							17.5
e																	2.5
ér	3.2	38.8	2.7	4.4						3.6	3.8						60.3
i														5.3			8.4
l																	4.2
o	4.6			24.2													31.9
ó																	3.9
ó	5.4									2.2							10.2
u								26.1		4.8					2.8		34.6
u																	11.8
ou																	5.6

Total number of sounds called _____   Letter Articulation _72.2_

Total number of errors _____

Vowel Articulation _83.4_   Word Articulation _41.2_

DESCRIPTION OF THE SYSTEM FOR REPRODUCING SPEECH SOUNDS.

The telephone system used in this investigation is probably more nearly perfect than any other which has yet been built. Its essential elements are a condenser transmitter to receive the speech waves and transform them into the electrical form, an amplifier for magnifying the intensity of the electrical speech currents, an attenuator for controlling the intensity, an equalizing network, and a receiver for delivering the speech to the ear. A schematic arrangement of the circuit is shown in Fig. 1.

FIG. 1.   •

High Quality Telephone System
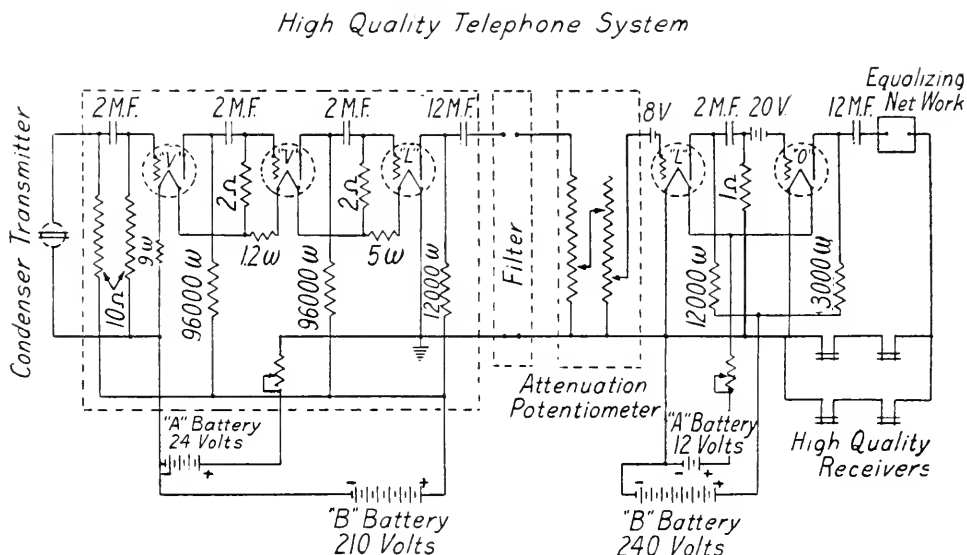
A detailed description of the construction and operation of the condenser transmitter has been given by Crandall and Wente and published in the *Physical Review*.[1] It is simply an air condenser, one of its plates being a flexible metal diaphragm.

A five-stage vacuum tube amplifier was used. Particular care was taken in coupling the stages together, so that the amplifier was practically free from frequency distortion.

The attenuator consisted of a potentiometer arrangement which could reduce the amplitude of the speech waves to approximately one-millionth of their maximum values.

The equalizing network was an arrangement of resistances,

---

[1] Crandall, *Phys. Rev.*, June, 1918; Wente, *Phys. Rev.*, July, 1917.

condensers and inductance coils having a frequency selectivity which was the complement of that of the rest of the system.

The telephone receiver was a bipolar type having a special construction which was designed to broaden the range of frequency response.

The reproducing efficiency of the system from the mouth of the speaker to the ear of the listener for each frequency is shown in Fig. 2.

FIG. 2.
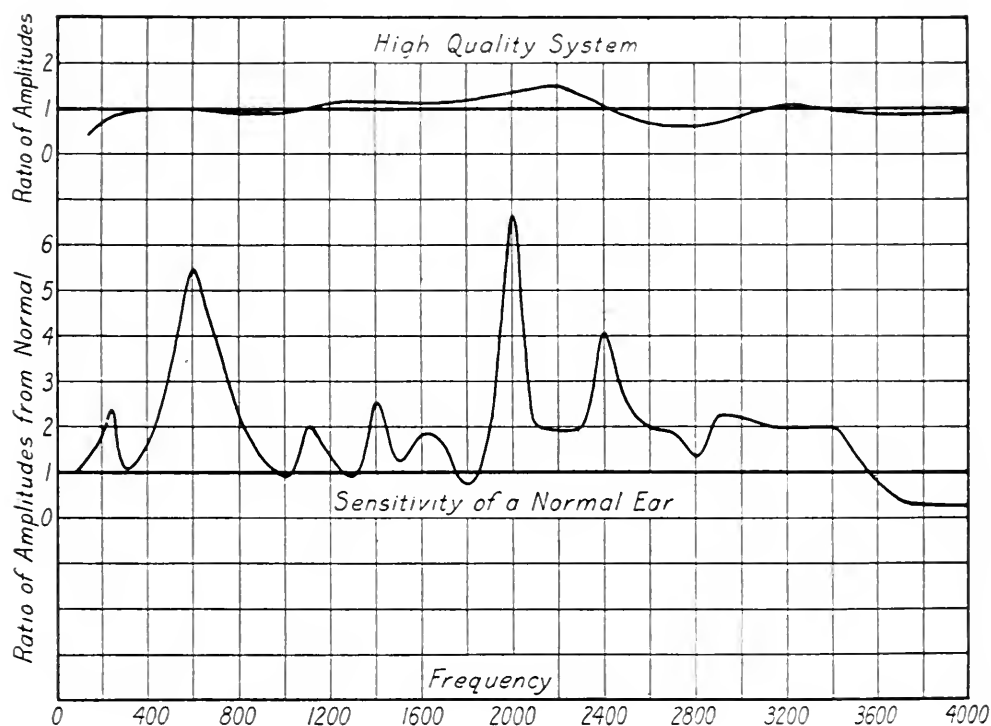
The pitch or frequency of the tone is given on the X axis. The ordinates represent amplitude ratios or the number of times the amplitude of the tone reaching the ear was greater than that which entered the transmitter. It will be seen that this high quality system has practically a uniform response for all frequencies throughout the speech range.

In order that its uniformity may be appreciated, a comparison curve is given. This curve shows the deviation in the sensitivity of a typical individual ear from the average sensitivity of a large number of ears. The ordinates represent the ratio of amplitudes at the various pitches which was necessary to bring the

tone to the threshold of audibility. It is evident that this deviation is much larger than the departure of the high quality circuit from uniformity.

FIG. 3.

Figure 3
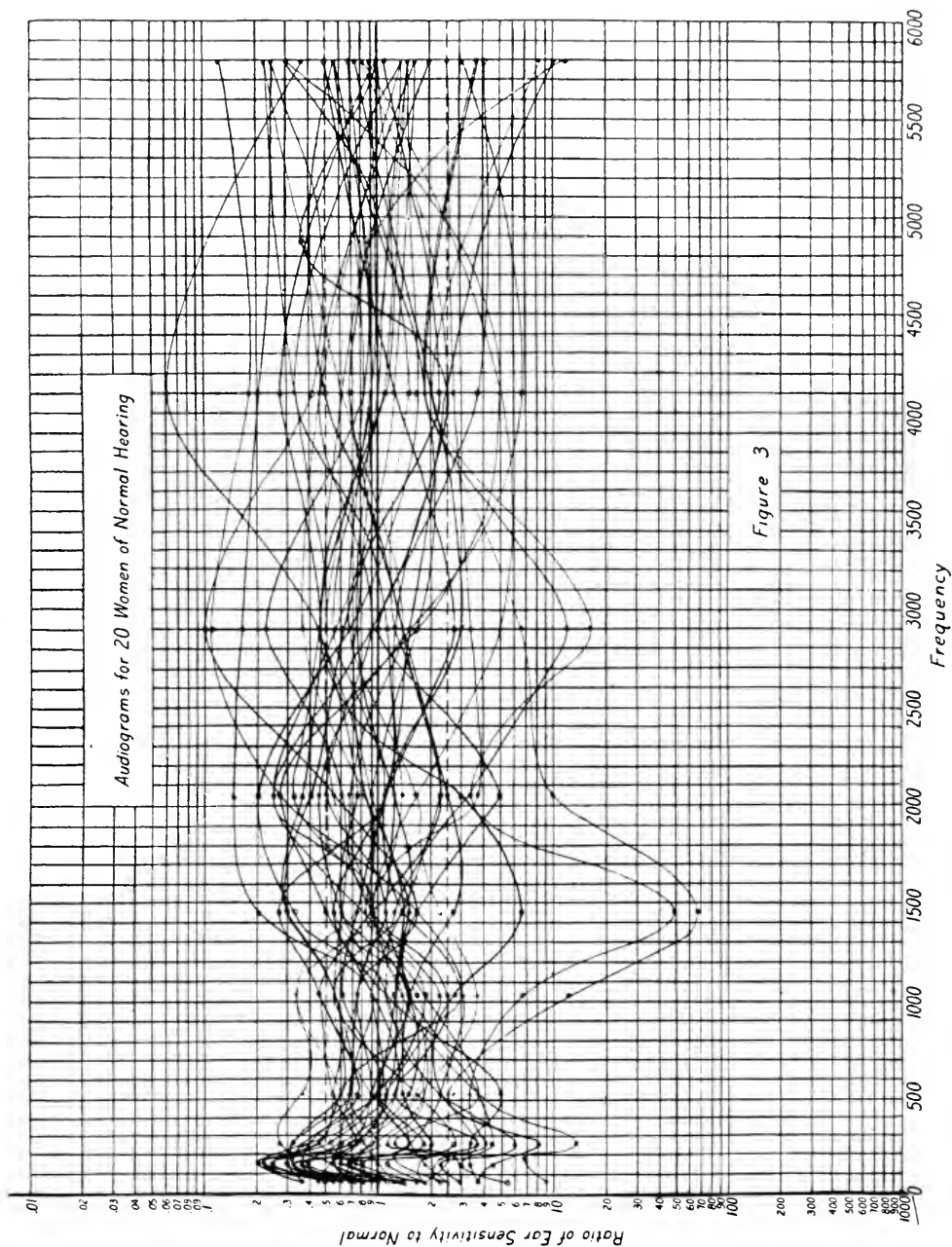
To show that this particular individual's curve is typical, the curves for both ears of 20 women are given in Fig. 3. For convenience these curves are plotted on logarithmic paper. If an arithmetic scale is used, all of the curves below the mean are

crowded together in the small space between zero and one, and all those above the mean are stretched out from one to infinity. By using a logarithmic plot a symmetrical distribution is obtained. The method of obtaining these ear sensitivity curves was fully described in a recent paper [2] given before the Natural Academy of Science.

It is interesting to note that they indicate that each individual has a hearing characteristic which is quite different from other individuals. Consequently speech sounds differently to different persons. Any distortions of the speech sounds will necessarily affect some persons differently from others. It is evident then that in discussing speech and hearing we must deal with statistical averages.

Experimental articulation tests showed that the ear interpreted the speech which was transmitted over this high quality system practically as well as that transmitted through the air. Some may wonder why such good quality is not furnished telephone users in commercial practice: Scientifically speaking, it is possible to furnish such quality, but it is evident that the equipment involved is so complicated that such service would be altogether too costly for commercial use; people could not afford to pay for it.

THE RELATION BETWEEN THE VOLUME AND ARTICULATION OF UNDISTORTED SPEECH.

Articulation tests were made upon the high quality telephone system described above when it was set to deliver various intensities from the threshold of audibility to very large values. The results shown as syllable articulation values are given by the curve on Fig. 4. The abscissas in this curve represent loudness and are expressed as the natural logarithm of the number of times the speech wave amplitude has been decreased from the initial intensity at $\frac{1}{2}$ inch in front of the mouth of the callers. This unit of loudness has never been given a name, and as a matter of convenience in this work it is called a napier. It will be noticed that when the volume is reduced $11\frac{1}{2}$ napiers below the initial speech intensity the articulation becomes zero. This point also represents the value at which the speech becomes inaudible and corresponds

---

[2] Fletcher and Wegel, *Proc. Nat. Acad. Science*, Vol. 8, No. 1, pp. 5-6, Jan., 1922.

to approximately 1/1000 dynes per square centimetre pressure variation against the ear drum. In energy units it is a reduction of ten billion times below the initial speech intensity. For very loud initial speech this point is shifted about 1 napier. For purposes of comparison the intensity reductions are also indicated on the loudness axis.

FIG. 4.
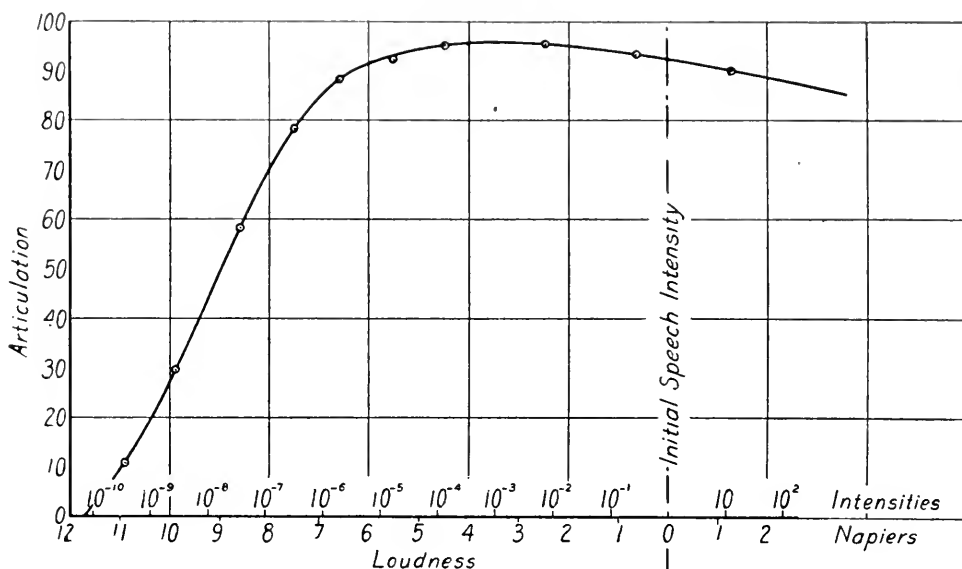
At 3 napiers below or at about 1/1000 of the initial speech intensity the articulation becomes a maximum. Louder speech than this seems to deaden the nerves so that a person makes a less accurate interpretation of the received speech. These results were obtained in a room which was especially constructed to exclude outside noise. When noise is present at the receiving station the optimum loudness increases as the noise increases.

The articulation data were analyzed so as to show the errors of each of the fundamental sounds. The curves given in Fig. 5 show the results of this analysis. It will be noticed that the volume at which errors begin to be appreciable is different for the different sounds and is usually higher for the consonants than for the vowels. Within the precision of the test the intersection point on the X axis was the same for all the sounds, namely at 11.5 napiers.

It will be noticed that the consonants are usually harder to hear than the vowels. However, the speech sounds e and l, r, ng form

notable exceptions to this general rule, since the former is among
the most difficult, while the latter are among the very easiest speech
sounds. The order in which the speech sounds are given here

FIG. 5.

Relative Difficulty of Fundamental Sounds
on the
High Quality Circuit
Articulation vs Volume
Abscissa measured in napiers
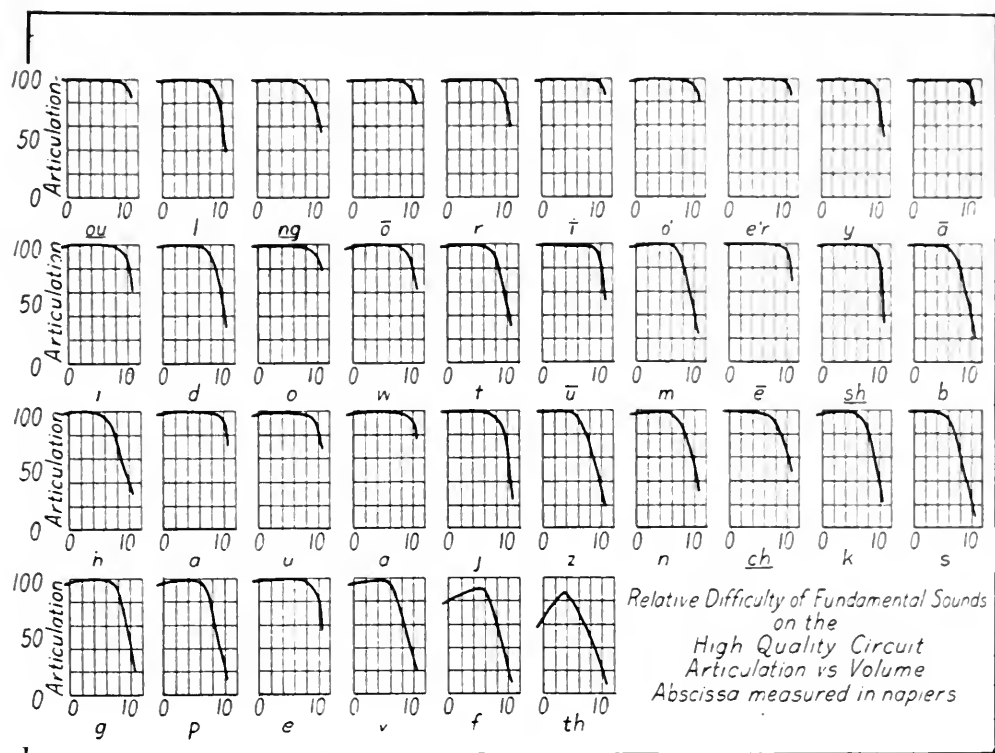
represents their relative difficulty of interpretation when received
at average intensities. At all intensities, the sounds th, f and v are
the most difficult. Z, h and s become very difficult at weak volumes.
The sounds i, ou, er and ó are missed less than 10 per cent. of the
time, even with " very weak " intensity. At " average " volumes
there are only three sounds more difficult than e while at " very
weak " volumes there are 23 sounds more difficult. At very weak
volumes l, which is the easiest sound at " average " volumes is
missed three times as often as e.

We will now pass to a consideration of the effect of distortion
upon the articulation of the sounds.

DESCRIPTION OF ELECTRICAL FILTERS USED TO PRODUCE DISTORTION.

In order to investigate distortion we would like to be able to
take the train of speech waves going from the mouth to the ear and
operate upon it in various ways such as eliminating frequencies

in certain regions without marring or disturbing other frequencies. For example if all frequencies above 1000 were eliminated it would be possible to determine what intelligibility is carried by this range of frequencies.

Fortunately one of the recent electrical inventions is admirably adapted for this purpose, namely, the electrical wave filter invented by Dr. G. A. Campbell. This device was used extensively in this investigation.

The schematic circuit diagrams of the two types of filters which were used are given in Fig. 6.

FIG. 6.

Low Pass Filter

High Pass Filter
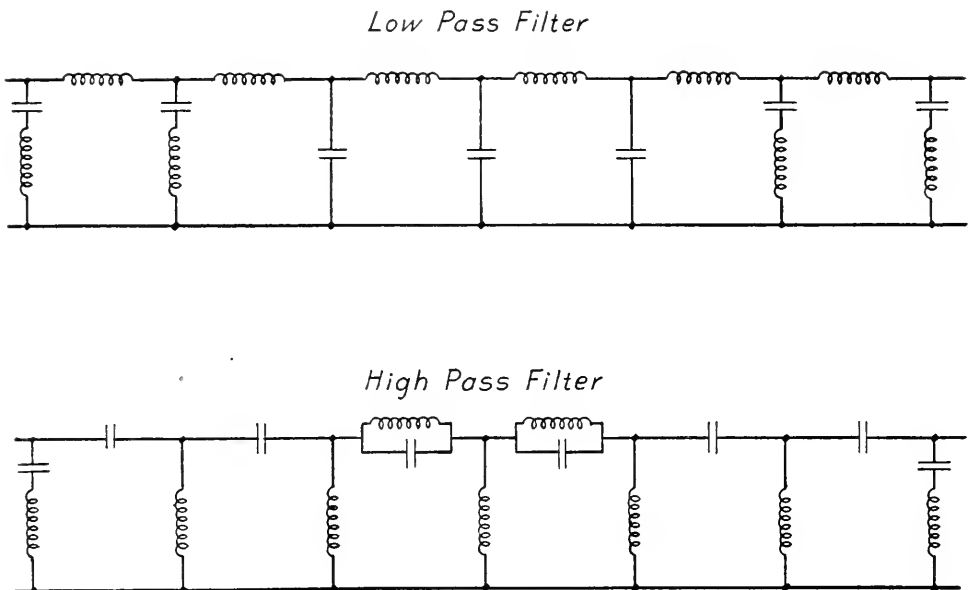
This arrangement of coils and condensers produces an electrical conductor with the unusual properties that it transmits without appreciable diminution in amplitude any frequency between certain limits and reduces the amplitude of all frequencies outside these limits to less than 1/1000 of their original value. By varying the numerical values of the inductances and capacities this transmitted range can be placed at any desired position. In the arrangement which was used in the investigation these coils and condensers were housed in two boxes. The switching mechanism was arranged so that by turning a dial the condensers and coils were connected in such a way that the filter transmitted different frequency bands.

In Fig. 7 are shown the transmission properties of the low pass filter when the dial is set to transmit frequencies from 0 to 1500. It is seen that for frequencies below 1400 the amplitudes of the transmitted tones are always greater than .8 of their initial values, while for frequencies above 1500 the amplitudes are decreased to less than .001 of their initial values. These electrical filters were connected into the high quality circuit between the third

FIG. 7.

Frequency Characteristics of 0-1500 Filter
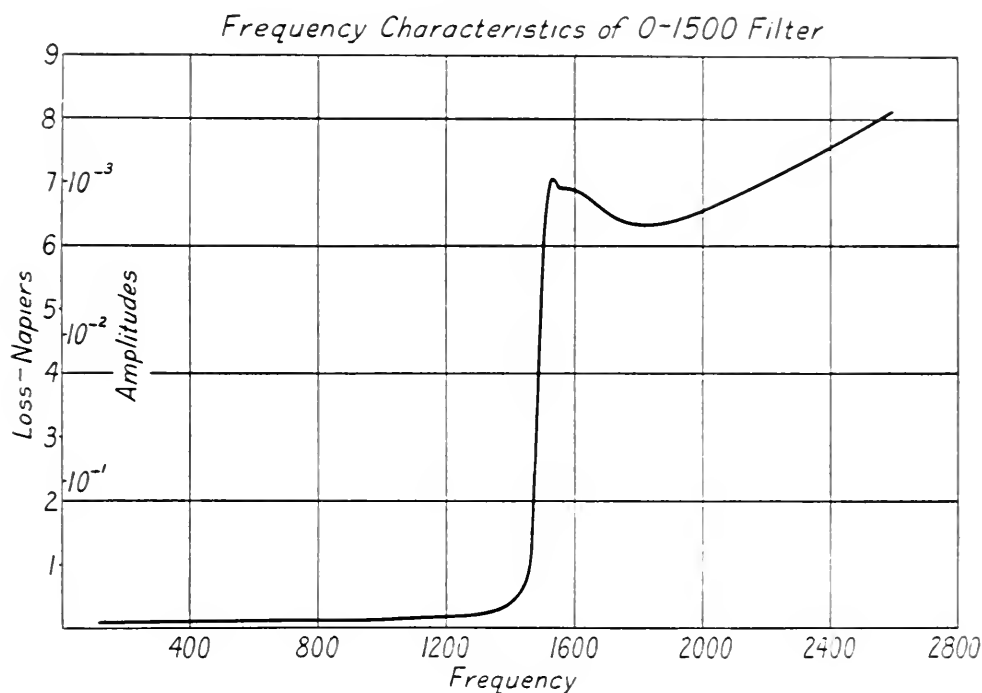
and fourth stages of the amplifier as indicated in Fig. 1. This combination formed a system which would pick up a complex sound wave and transmit faithfully to the ear those component frequencies in any desired region and eliminate all other frequencies.

RESULTS OF ARTICULATION TESTS WITH FILTER SYSTEMS.

Articulation tests were made with these filter systems and the results analyzed as described above. In Fig. 8 the syllable articulation results are shown in graphical form. The ordinates for the solid curves represent the per cent. of the articulation syllables called into the system which were correctly recorded at the observing end. The abscissas represent the so-called "cut off" frequency

of the filter. For example on the curve labelled "Articulation L" the point (1000, 40) means that a system which transmits only frequencies below 1000 cycles per second has a syllable articulation of 40 per cent. Similarly on the curve labelled "Articulation H" the point (1000, 86) means that a system which transmits only frequencies above 1000 cycles per second has a syllable articulation of 86 per cent. The dotted curves show the per cent. of the total

FIG. 8.

Effect upon the Articulation and the Energy of Speech of Eliminating Certain Frequency Regions
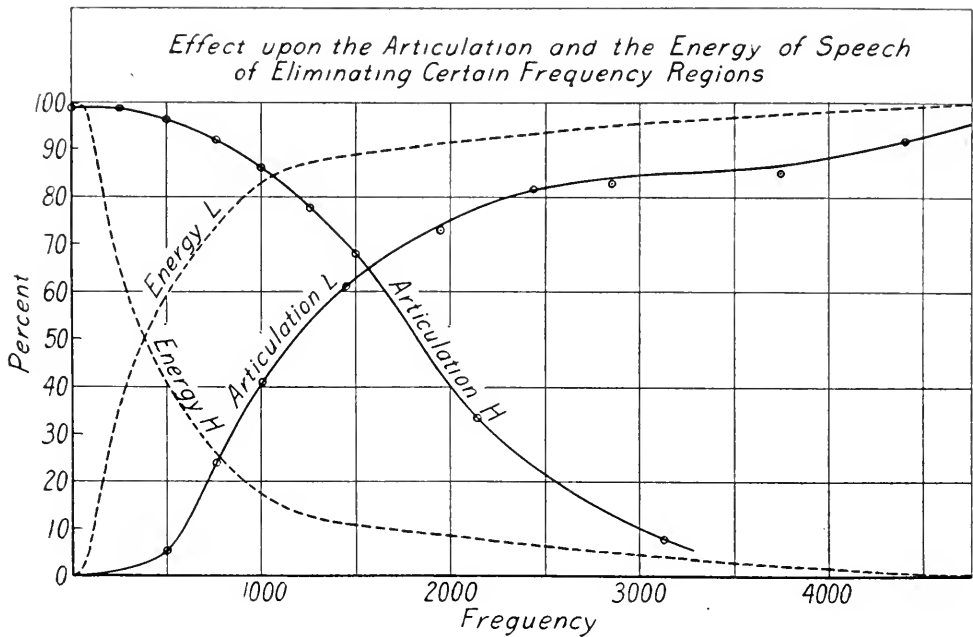
speech energy which is transmitted through the filter systems used in the articulation tests. These curves are derived from the results of Crandall and MacKenzie which were recently published.[3]

It will be seen that although the fundamental cord tones with their first few harmonies carry a large portion of the speech energy, they carry practically none of the speech articulation. A filter system which eliminates all frequencies below 500 cycles per second eliminates 60 per cent. of the energy in speech, but only reduces the articulation 2 per cent. A system which eliminates frequencies above 1500 cycles per second eliminates only 10 per cent. of the speech energy, but reduces the articulation 35 per cent. A system which eliminates all frequencies above 3000 cycles per second has as low a value for the articulation as one which eliminates all frequencies below 1000 cycles per second. This last statement may

[3] *Phys. Rev.,* March, 1922.

appear rather astonishing since it is contrary to the popular notion of the relative importance of various voice frequencies from an interpretation standpoint.

The two solid curves intersect on the 1550 cycle abscissa and at 65 per cent. articulation, which shows that using only frequencies above or frequencies below 1550 cycles an articulation of 65 per cent. will be obtained. The two dotted curves necessarily intersect at 50 per cent.

The curves in Fig. 9 show how the articulation of some of the fundamental speech sounds was affected by eliminating certain frequency regions. The ordinate gives the number of times the sound was written correctly per 100 times called. As in Fig. 8 the left hand curve shows the effect of eliminating all frequencies below and the right hand curve the effect of eliminating all frequencies above the frequency specified by the abscissa.

These nine speech sounds were chosen as representing three important classes. It is seen that the long vowels ē, l and ī can be transmitted with an error of less than 3 per cent. when using either half of the range of frequencies. When using either frequencies from 0 to 1700 or from 1700 to infinity ē was interpreted correctly 98 per cent. of the time. Similarly l was interpreted correctly 97 per cent. of the time when using either the range from 0 to 1000 or 1000 to infinity, and ī 96 per cent. of the time when using either the range from 0 to 1350 or from 1350 to infinity. The short vowels, u, o and e are seen to have important characteristics carried by frequencies below 1000. More than a 20 per cent. error is made on any of these three sounds when frequencies below 1000 are eliminated. The elimination of frequencies above 2000 produces almost no effect.

The fricative consonants s, z and th are seen to be affected very differently from those in the other two classes. These sounds are very definitely affected when frequencies above 5000 are eliminated. The sounds s and z are not affected by the elimination frequencies below 1500. It is principally due to these three sounds that the syllable articulation is reduced from 98 per cent. to 82 per cent. when frequencies above 2500 cycles are eliminated.

A more detailed analysis of the articulation results on all the speech sounds showing the kind as well as the number of errors will be given in a future paper.

FIG. 9.
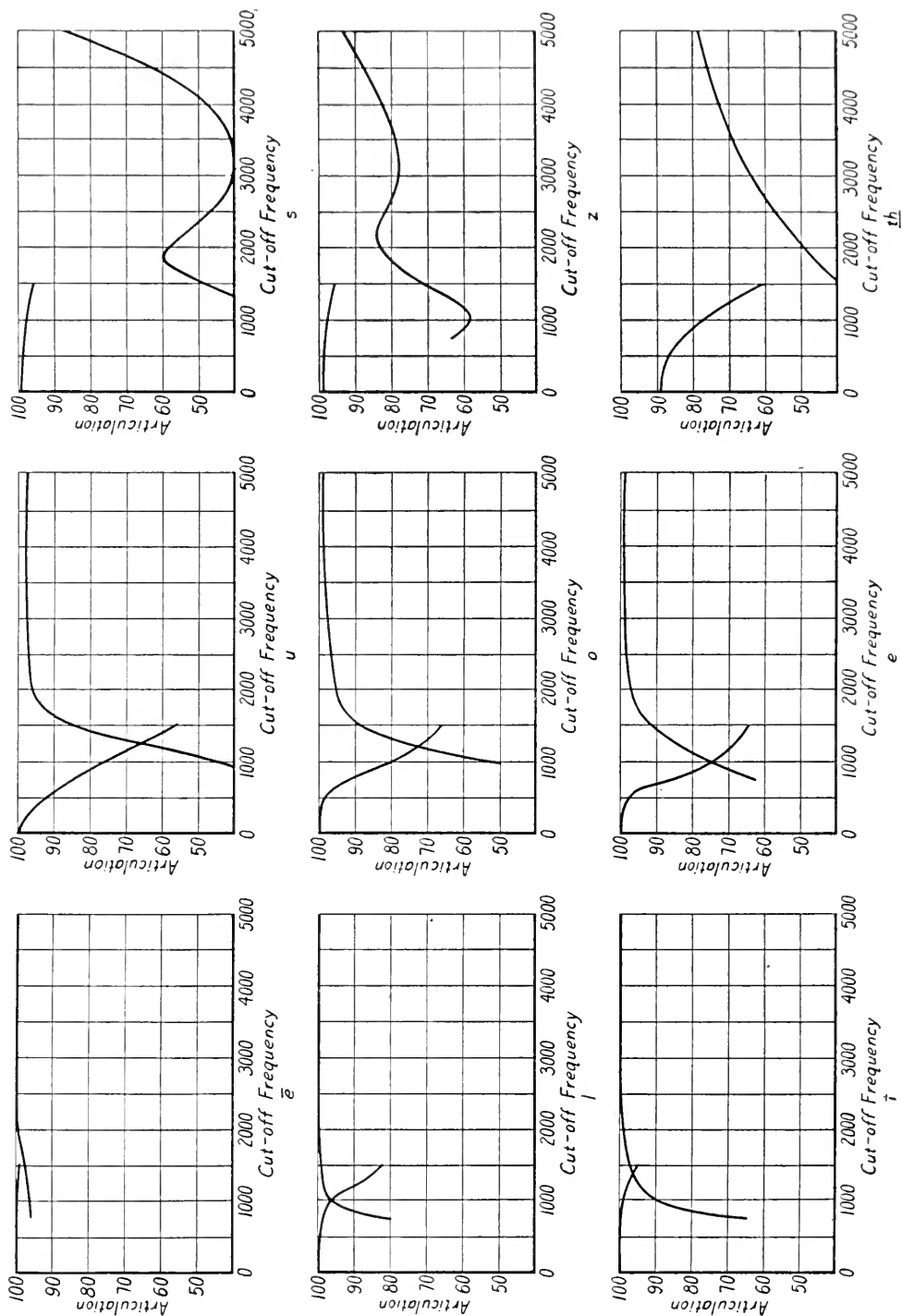
CONCLUSION.

In conclusion then we see that the intensity of undistorted speech which is received by the ear can be varied from 100 times greater to one-millionth less than the initial speech intensity without noticeably affecting its interpretation. The intensity must be reduced to one-ten-billionth of that initial speech intensity to reach the threshold of audibility for the average ear. Also it is seen that any apparatus designed to reproduce speech and preserve all of its characteristic qualities must transmit frequencies from 100 to above 5000 cycles with approximately the same efficiency. Although most of the energy in speech is carried by frequencies below 1000, the essential characteristics which determine its interpretation are carried mostly by frequencies above 1000 cycles. In ordinary conversation the sounds th, f and v are the most difficult to hear, and are responsible for 50 per cent. of the mistakes of interpretation. The characteristics of these sounds are carried principally by the very high frequencies.

It is evident that progress in the knowledge of speech and hearing has a great human interest. It will greatly aid the linguists, the actors, and the medical specialists. It may lead to improved devices which will alleviate the handicaps of deaf and dumb persons. Furthermore this knowledge will be of great importance to the telephone engineer, and since the telephone is so universally used, any improvement in its quality will be for the public good.

These humanitarian and utilitarian motives as well as the pure scientific interest have already attracted a number of scientists to this field. Now that new and powerful tools are available, it is expected that in the near future more will be led to pursue research along those lines.

LONG-DISTANCE RADIO COMMUNICATION.

BY

L. W. AUSTIN, PH.D., D.Sc.

APRIL, 1922, ISSUE, PAGE 437.

CORRECTION.

Page 445, line two, should read:
at Cavite is 200 amperes and the wave-length 12,100 metres.

An Attempt to Determine Whether a Minimum Time is
Necessary to Excite the Human Retina. J. H. J. POOLE. (*Phil.
Mag.*, February, 1922.)—The general method employed was this:
Light, from a small incandescent lamp passed through a lens, fell
upon a plane mirror mounted on top of the vertical shaft of a cen-
trifuge and, after reflection, reached a slit behind which was the eye
of the observer. The lens caused the image of the filament to fall
upon the slit. When the centrifuge rotated 8000 r.p.m. the eye
received light for only a small part of each revolution, but there
were many successive flashes in a second. To cut down this number
a sectored wheel was interposed between the lamp and the lens.
The experiments were conducted in a cellar in order to command
large distances and to secure entire darkness.

The adaptation of the eye in the dark is an important factor in the
experiments. It takes at least 45 minutes in darkness to attain the
greatest sensitiveness, but after 25 minutes the gain is very slow.
The eye adapted in the dark is from 5000 to 10,000 times as sensitive
as in ordinary daylight.

The duration of the flash received by the eye of the observer
could be calculated from the dimensions of the apparatus and the
speed of rotation. " It was found that a flash of two ten-millionths
seconds was still visible. A flash of duration eight hundred-millionths
seconds was, however, found to be invisible. The energy in each of
these flashes could be approximately calculated from the candle-
power of the radiant and the various dimensions of the apparatus,
and it was found that, neglecting any loss by reflexion, etc., the
energy in the visible flash was about four ten-millionths erg, while
that in the invisible flash was about eight hundred-millionths erg.
As to whether the invisibility of the shorter flash is due to its
smaller duration alone or simply to the decrease in the energy
available, is uncertain. It seems, however, that the latter hypothesis
is more probable as the intensity of the longer flash was exces-
sively feeble."   G. F. S.

Fertilizer from Wool-scouring Wastes.—F. P. VEITCH (*Jour.
Ind. Eng. Chem.*, 1922, xiv, 434) states that, on the average, un-
scoured wool contains 4 per cent. of water-soluble potash and 0.6 per
cent. of water-soluble nitrogen. Both the potash and the nitrogen
are present in the wool as water-soluble compounds which are
removed by scouring and pass into the sewage from the scouring
plant. In this way water courses are polluted, and much valuable
fertilizer is lost. In fact, potash worth $840,000 and nitrogenous
compounds worth $280,000 as fertilizer are wasted annually. The
liquor obtained by scouring may be concentrated and mixed with the
wastes from other industries to produce a satisfactory fertilizer.
                                                              J. S. H.

PHYSICAL CHEMISTRY AND CERAMICS.*

BY

EDWARD W. WASHBURN, PH.D.

Department of Ceramic Engineering, University of Illinois.

I. INTRODUCTION.

Ceramics.—The term "ceramics" is derived from the Greek "*keramos*" which in turn is related to an older Sanskrit root, meaning "to burn." As used by the Greeks themselves, the primary meaning of "keramos" was simply "burnt stuff," that is, a product obtained by the action of fire, usually upon earthy materials. Modern technical usage in this country is in accord with the original Greek usage, that is, the ceramic industries are those industries which manufacture products by the action of heat on raw materials which are chiefly of an earthy nature. Among these raw materials the element silicon, in the form of its oxide and the compounds thereof (the silicates), occupies a predominant position. In accordance with this definition, the products of ceramic industries include the following:[1]

(1) All kinds of burned clay products, such as stoneware, earthenware, brick, tile, sewer pipe, terra cotta, china, porcelain and so forth.

(2) Cementing materials, such as Portland cement and dental cements; lime, plaster, and a variety of magnesia and gypsum products whose constituents are of an earthy nature and which, after a preliminary treatment which involves a calcination, acquire the property of "setting" to a greater or less extent, when mixed with the proper liquids.

(3) All varieties of glass and glassware including quartz glass, glazes, enamels and many of the artificial precious stones.

(4) Enameled metal products, where the enamel itself is a ceramic material applied to the metal at high temperature, the

---

* Presented at a meeting of the Section of Physics and Chemistry of The Franklin Institute held Thursday, April 6, 1922.

[1] "Rep. of Comm. on Definition," *Jour. Amer. Ceram. Soc.*, **3**, 526 (1920).

metal serving only as a skeleton to give the desired form and strength to the glass which it supports.

(5) Refractory articles or materials, either wholly or partially composed of or manufactured from clay, silica (in its various forms), alumina (bauxite), magnesia (magnesite), lime, chromite, asbestos, zirconia, mica, the rare earths, certain carbides and nitrides, and in general any non-metallic product capable of withstanding elevated temperatures. In the case of all products of this class it is evident that a high temperature treatment is fundamental.

(6) Abrasive materials such as carborundum, alundum, and zirconia (and by association, finely divided silica and emery), together with the products manufactured from them by bonding with an earthy material.

(7) Various electrical and thermal insulating products in the manufacture of which earthy materials enter as an important element.

Physical Chemistry.—Physical chemistry is coming to be not so much a definite branch or field of chemistry as it is an attitude or point of view and method of approach to problems in all branches of chemistry. The physical chemists have discovered laws and principles, developed theories and systems of classification, and devised methods and apparatus which have been very successful in enlarging our scientific knowledge of the character and behavior of a great variety of physico-chemical systems. In this way, physico-chemical principles and physico-chemical methods have been successfully employed in the solution of many of the problems of inorganic, organic, physiological, ceramic, mineralogical, geological, sanitary, industrial, analytical, radio and astronomical chemistry.

A discussion of the subject, Physical Chemistry and Ceramics, can therefore be little else than a presentation of examples of ceramic systems in the study of which the methods of the physical chemist have been or might be advantageously employed. I shall, therefore, devote the remaining portion of the discussion to the enumeration and description of instances of this character. Since it is necessary to restrict the scope of the discussion it will be confined to the following five subjects: (1) Colloid chemistry and ceramics; (2) heterogeneous equilibrium at high temperatures; (3) properties of silicate solutions at high temperatures;

(4) high temperature calorimetry; (5) standard methods for testing ceramic materials and products.

II. COLLOID CHEMISTRY AND CERAMICS.

The material to which the term clay is applied is a typical disperse system. Indeed the important properties of plasticity and drying behavior are practically dependent upon the degree of dispersion of the clay material and are to a considerable extent independent of the chemical and mineralogical nature of the particles which make up the clay. From the time the clay is first treated with water in preparation for shaping the body, up to the time when vitrification is well advanced, the clay worker is dealing with a typical colloid.

The phenomenon of plasticity, its magnitude, and the amount of water required to produce its maximum value; the strength of the plastic body, its mobility, its "yield value" and its drying shrinkage are all largely determined by the sizes and size distribution of the individual particles which make up. the clay mass. Unfortunately the quantitative relations connecting the above-mentioned properties are at present only slightly and imperfectly known.

The air-dried clay body contains a large quantity of adsorbed water, whose vapor pressure is considerably lower than that of liquid water and which consequently requires higher temperatures for its expulsion. Large quantities of adsorbed permanent gases are also present, both in the raw clay and in the dried body. These gases can be pumped out by heating the clay to about 500° in a suitable vessel connected to a vacuum pump. The resulting dehydrated and out-gassed material possesses pronounced catalytic powers. The amounts and nature of the adsorbed gases have not been systematically studied, nor has the vapor pressure curve of the adsorbed moisture been determined. Both classes of adsorbed materials undoubtedly play an important rôle in the early stages of the firing process and the presence of adsorbed moisture in the right amount is necessary for the shaping of ceramic wares by the dust-press process. There is a large field here for physico-chemical investigation.

The phenomena of deflocculation and flocculation, or peptization and coagulation as they are usually termed by the colloid chemist, are exhibited by all water-clay systems, and are made use

of by the clay worker for purifying his material and in preparing his "slips" for the "casting" process. The physical chemistry of these processes as they take place with clay has received considerable investigation. In general we may say that hydroxyl-ion is a peptizer for clay particles, and definite laboratory methods for determining the proper amounts of water and of peptizer to use in preparing clay slip for a given purpose have been worked out. In some cases the dispersing power of this peptizer is so great that a mass of moist plastic clay can be converted into a comparatively fluid liquid merely by the addition of a small quantity of an alkali.

The phenomenon of cataphoresis is, of course, exhibited by the clay particles in a colloidal suspension and has been studied to some extent with the idea of employing the electric current for the separation and removal of undesirable constituents from the raw clay.

The development of general quantitative laws in the colloid chemistry of clays is rendered difficult by the exceedingly complex nature of the materials dealt with. Only through careful fractionation of the clay, by sedimentation or centrifugation, into portions of definite composition and of uniform particle size, may we hope to obtain systems of sufficiently definite character to make it possible to largely increase our *scientific* knowledge in this field.

In addition to the clay colloids, disperse systems and colloidal processes are met with in ceramics in connection with the preparation and "setting" of cements, limes, and plasters, and in the manufacture of enamels, opalescent glasses, and certain colored glasses such as the gold ruby.

A physico-chemical investigation [2] of the raw material flint, which is a chalcedonic form of silica used in the pottery industry, has shown that it also consists principally of colloidal particles (quartz) and a satisfactory interpretation of its somewhat peculiar behavior on calcination has been obtained as a result of this study. In this investigation the X-ray spectrum apparatus was employed for the final elucidation of the problem. This is probably the first instance in which this new and powerful research tool has been employed in a ceramic investigation. It will in the future undoubtedly be largely used for the study of ceramic materials and products.

---

[2] *Proc. Nat. Acad. Sci.*, **8**, 1-5 (1922).

III. HETEROGENEOUS EQUILIBRIUM AT HIGH TEMPERATURES.

The Dissociation of Kaolin.—A considerable amount of the water present in clay is in a chemically combined condition. One

Fig. 1.
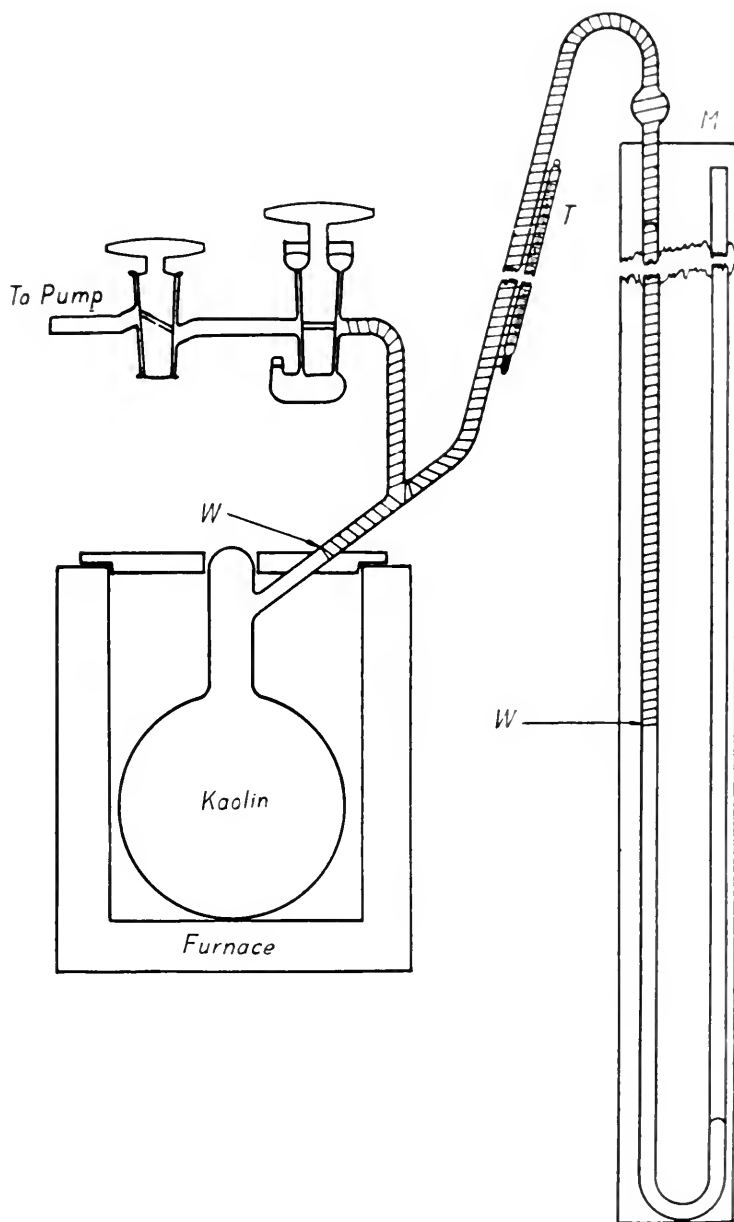
Apparatus for determining the adsorption vapor pressure and the dissociation pressure of kaolin by the static method.

of the most common mineralogical constituents of clay is the substance, kaolin, which, in the purest form in which it is found in nature, is a crystalline mineral (kaolinite) having the chemical composition, $Al_2O_3.2SiO_2.2H_2O$. When a body made of a kaolin

is fired, one of the processes which occurs and completes itself
during the early stages of firing is the decomposition of the kaolin
molecule with the elimination of the water as vapor. It is not
known whether the other constituents of the kaolin molecule

FIG. 2.
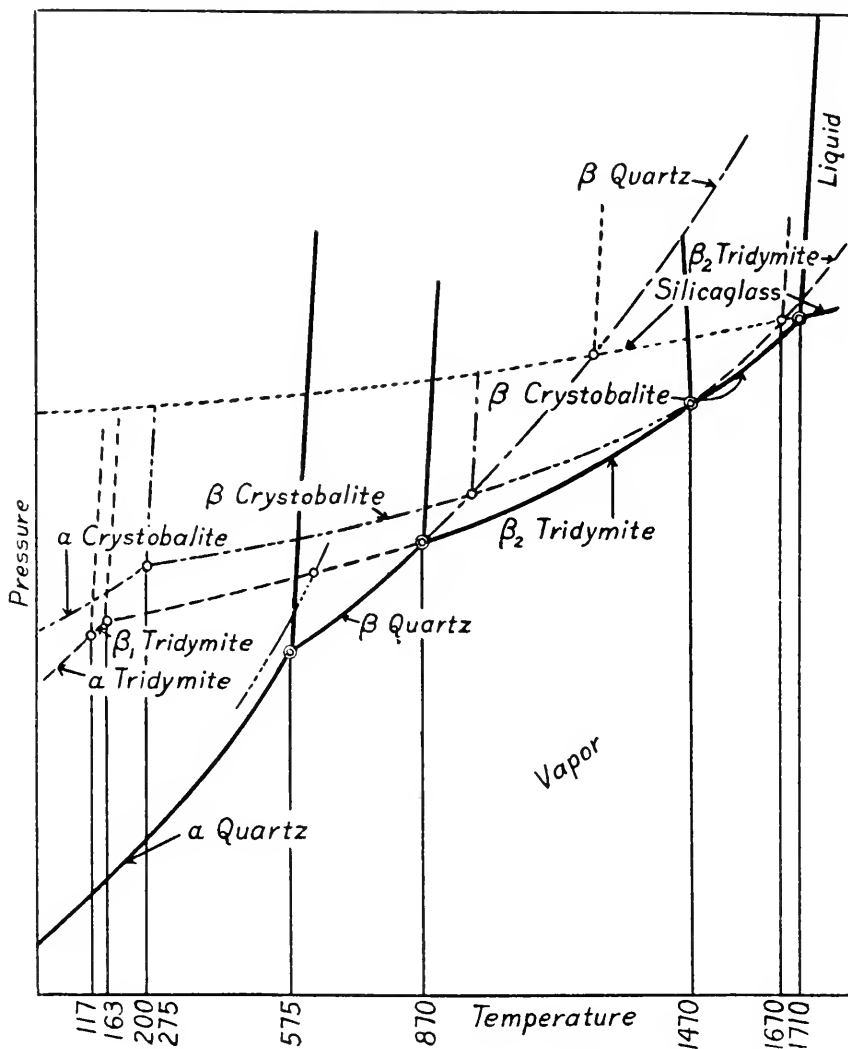
The phase rule diagram for the system SiO_2 showing stable and metastable melting and
transition temperatures. The volume changes on passing through the transition temperatures
are important and are all known.

remain combined after dehydration or whether they are obtained
simply in the form of highly dispersed, possibly amorphous, silica
and alumina. A physico-chemical study of the dissociation equi-
librium of kaolin at different temperatures would throw much light
upon the nature of the process and would, of course, make it pos-
sible to calculate thermodynamically the heat of the dehydration

reaction, that is, the amount of heat which must be added to the clay body in order to completely remove the chemically combined water. An investigation of this reaction has been started in the Illinois laboratories, using both the static and the dynamic methods. The principle of the static method is illustrated in Fig. 1. The dynamic method consists simply in passing known quantities of air over an intimate mixture of kaolin with its dehydration products

FIG. 3.
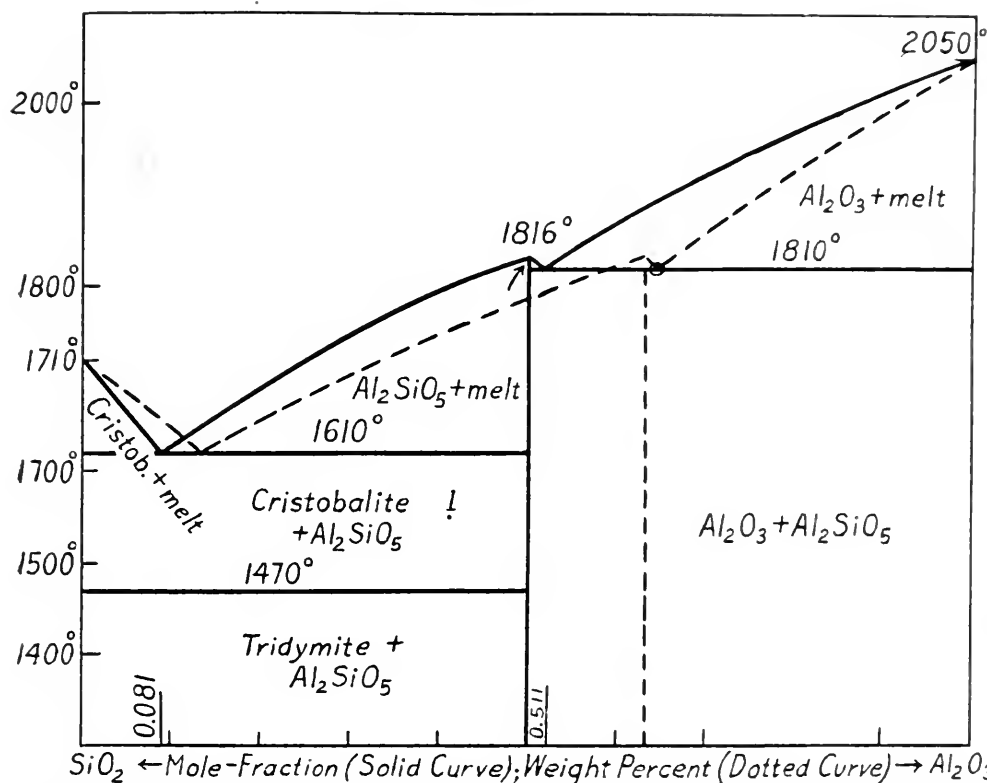
The phase rule diagram for the system SiO_2-Al_2O_3. Dehydrated kaolin belongs to this system. The heat of fusion of SiO_2 can be computed by applying the Solution Laws to this diagram.

kept at a definite temperature, and determining the water content of the air in equilibrium with the mixture.

Phase Rule Diagrams.—The determination of the melting and transition points of any of the earthy oxides used as raw materials in the ceramic industries is not a particularly difficult problem, and most of the melting points are now fairly well known. Since, however, most ceramic bodies are complex systems made up from 2, 3 or more earthy oxides, the phase rule diagrams of the various systems which can be produced with the different oxides are

important, especially for the cement manufacturer, for the manufacturer of bodies which must withstand high temperatures (refractories), as well as for the manufacturer of glass, whose product is a supercooled silicate solution, in which devitrification, that is, crystallization, must be avoided. Most of the phase rule

FIG. 4.
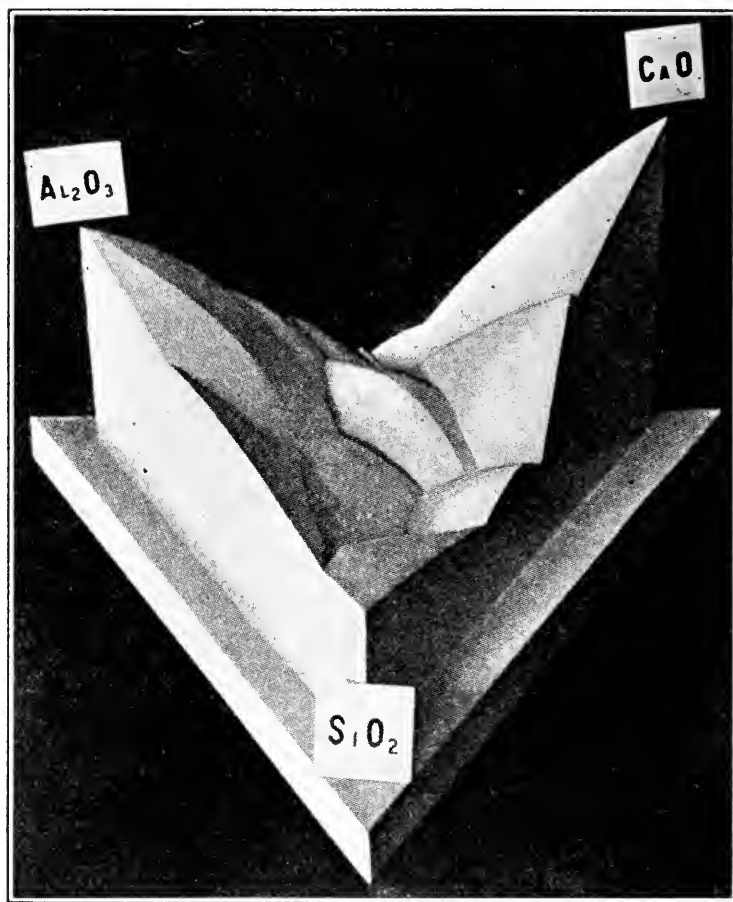
The phase rule diagram for the system SiO_2-Al_2O_3-CaO. Portland cement belongs to this system.

diagrams for ceramic systems which are known at present are the result of the systematic physico-chemical investigations carried out at the Geophysical Laboratory in Washington. Figs. 2, 3, and 4 illustrate the phase rule diagrams of some of the important ceramic systems.

With the aid of these diagrams it is possible to understand and interpret the behavior of ceramic bodies during firing and to

compute for example, the temperatures at which melting will begin and end as well as the amount of the body which can be melted at any given temperature. In the production of a refractory body from any given 2 or 3 oxides as components, the phase rule diagram enables one to tell at once what the possibilities are and

FIG. 5.

Lump of glass before melting.

what the best compositions are as regards resistance to the fluxing action of high temperatures. The more diagrams of this character there are available, and the greater the number of constituents which are covered by the diagrams, the more perfect will become our knowledge of the firing behavior of ceramic bodies and the nature of the attained and attainable completed products.

IV. PROPERTIES OF SILICATE SOLUTIONS AT HIGH TEMPERATURES.

If we carefully cool water, it is possible to cool it considerably below its freezing point before freezing sets in. As the temperature falls the viscosity of the water increases, but never becomes great enough to seriously interfere with that freedom of molecular movement which is necessary in order that the water molecules may arrange themselves into the geometric forms which we call

Fig. 6.
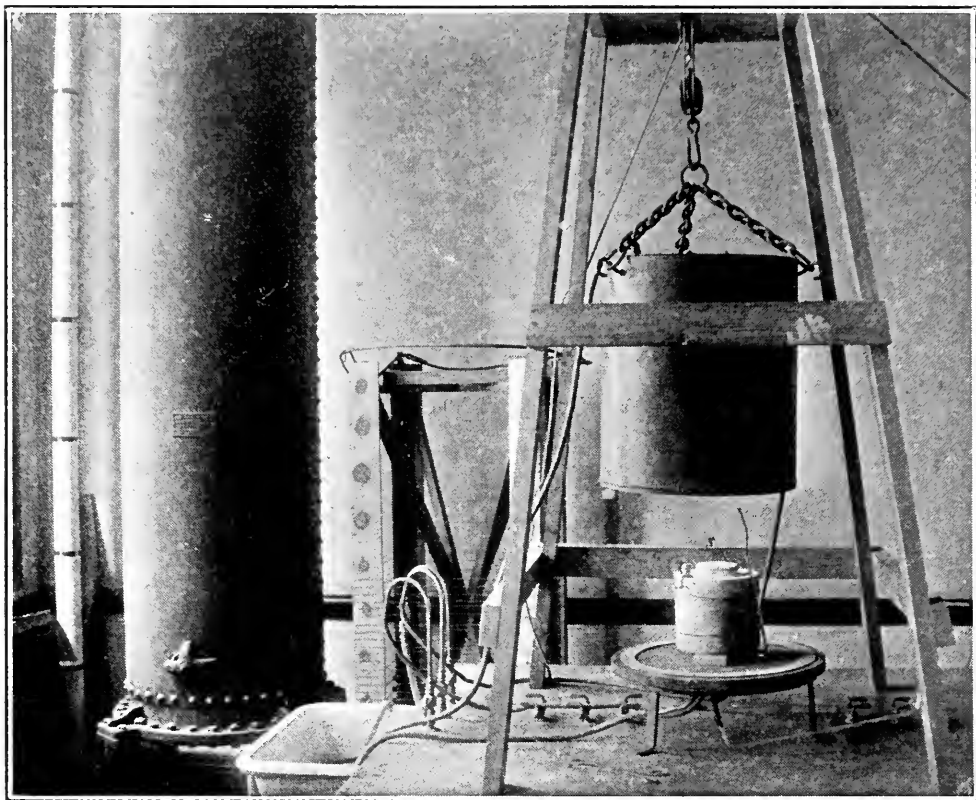
Vacuum furnace. The water-jacketed iron cylinder seats on a rubber gasket on the water-cooled base plate.

crystals. In other words, it has not been possible to supercool water indefinitely without the appearance of the crystalline phase, ice. If, however, we dissolve in the water some material such as sugar, we can prepare a solution or syrup which is very viscous, and on cooling this solution the viscosity increases so rapidly and becomes so great that the molecules of water and of sugar become practically fixed in position and are no longer able to move about with sufficient ease to allow them to group themselves into the geometric forms which we call ice crystals and sugar crystals. In other

words, as the temperature falls, the viscosity continues to increase until finally the syrup becomes hard and brittle, in other words, it is a *glass*, that is, a solid liquid, composed of sugar and water. In the same way the ordinary glass of commerce is a solid supercooled solution of silica and other oxides. A glass differs from a crys-

FIG. 7.
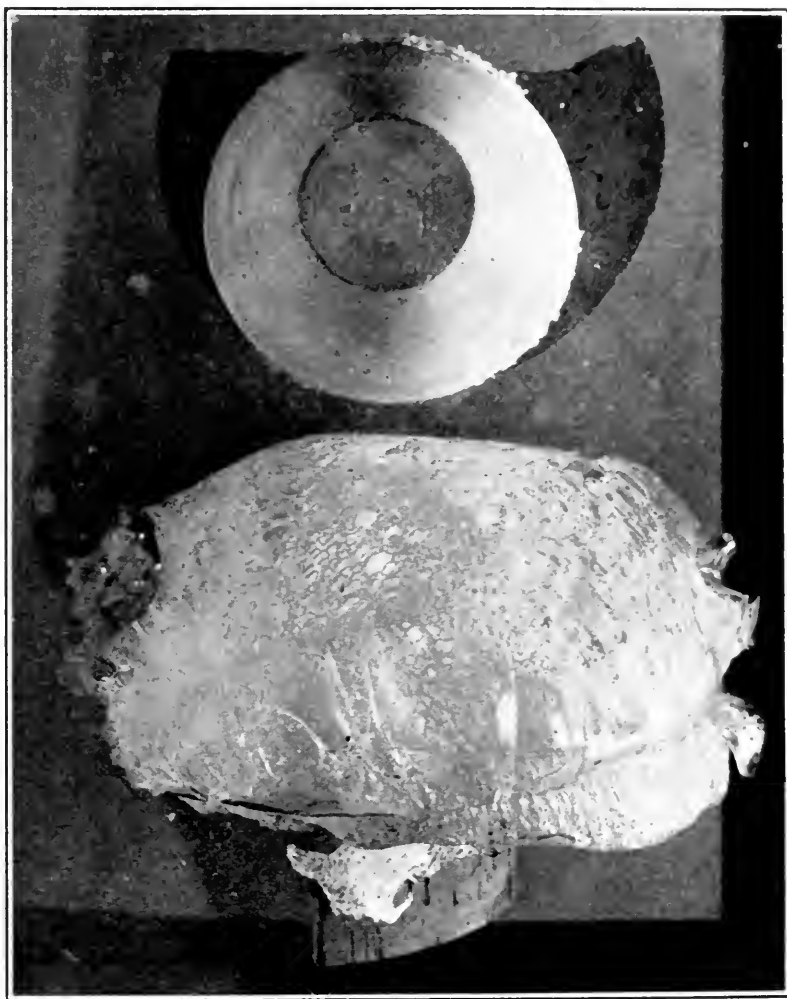
Lump of glass after melting followed by sudden reduction of pressure within the furnace.

talline solid not only in the absence of all crystalline structure, but also in the fact that it has no definite melting point, that is, there is no temperature at which we can say that glass changes from a solid to a fluid. The effect of increased temperature on the glass is simply to gradually soften it, the decrease in the viscosity with increase in temperature being a gradual and continuous process.

Glass is thus a liquid at all temperatures, a very viscous and therefore solid liquid at ordinary temperatures, and a comparatively mobile and fluid liquid at very high temperatures.

The physico-chemical study of aqueous solutions and in general of solutions which are liquid and fluid at ordinary temperatures

FIG. 8.
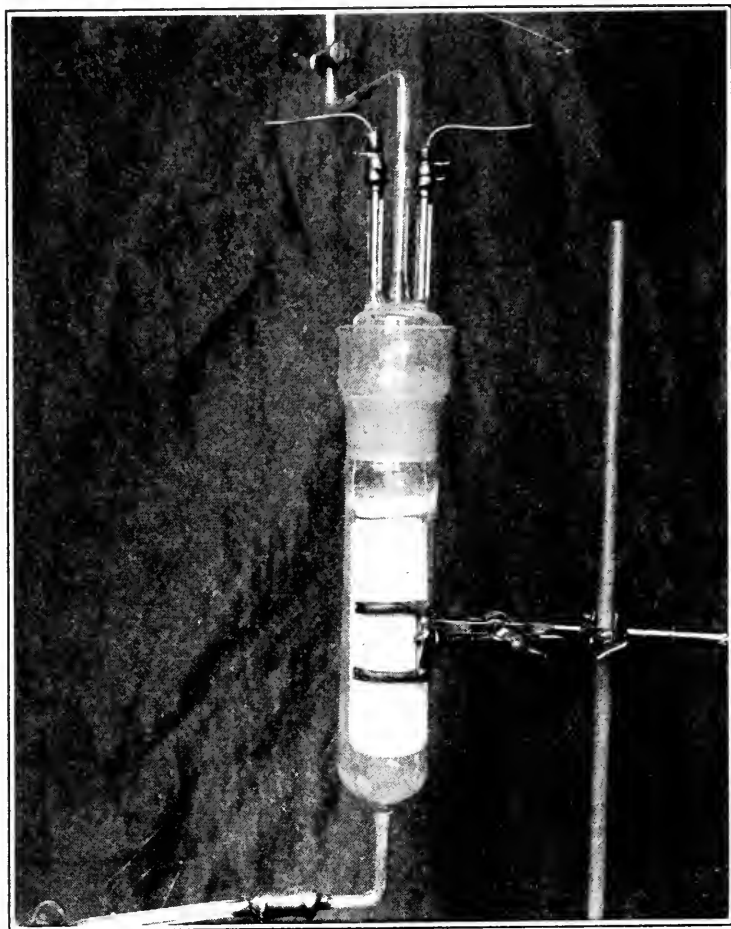
Apparatus for removing, measuring and analyzing the dissolved gases in glass.   The glass tube is first evacuated to a high vacuum, the glass in the porcelain crucible is then brought to 1400° and finally allowed to cool to room temperature.   The pressure of the evolved gas is measured and by admitting mercury through the inlet at the bottom, the gas is driven out into an Orsat apparatus and analyzed.

has yielded a vast amount of information and has given us numerous laws which have enabled us to systematize our knowledge of the properties and behavior of such solutions. In order to obtain similar knowledge concerning silicate solutions under conditions where the molecules in the solution have freedom of motion, it is necessary to work at elevated temperatures and, except

for the practical difficulties connected with working and making measurements at high temperatures, the methods of attacking the problems of silicate solutions are in no way different from those which have been so successfully employed in the case of aqueous

FIG. 9.
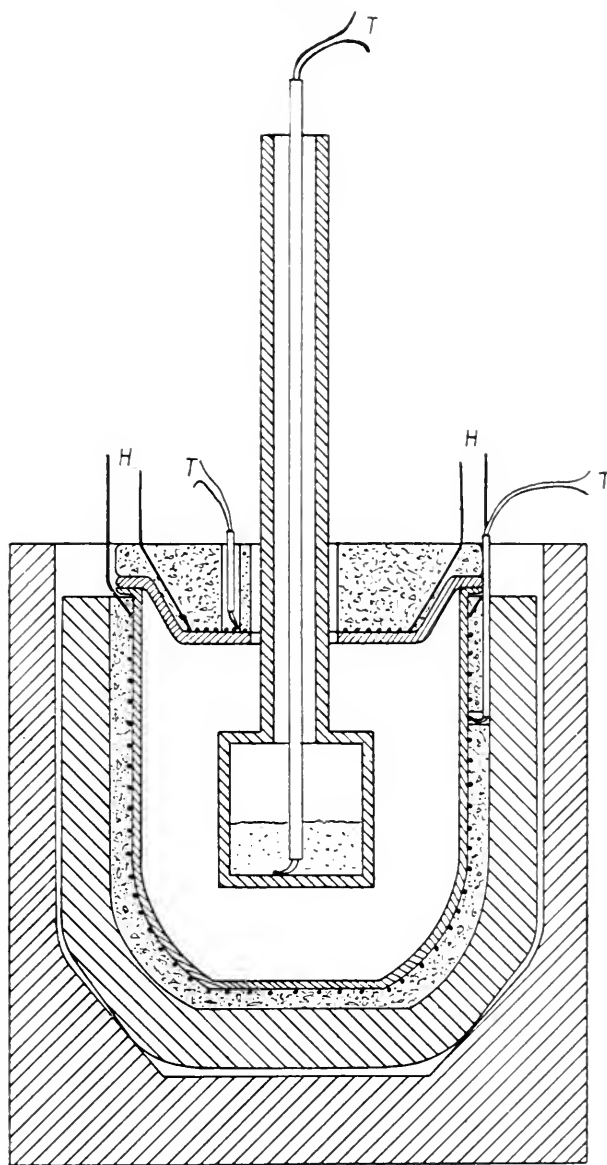
Rotating cylinder apparatus for measuring the viscosity of glass.
H, heating coils; *T*, thermocouples giving identical temperature readings.

solutions at ordinary temperatures. The difficulties associated with accurate physico-chemical measurements at high temperatures are however very real ones, and this is doubtless the reason why so little progress has been made in this field.

We have been attempting at Illinois during the past few years a systematic study of the physical properties of silicate solutions at high temperatures for the purpose of obtaining accurate values of these properties and of correlating, if possible, the data obtained with the composition of the solution. The properties to be investigated naturally include the phase relations (*e.g.*, freezing points and solubilities), density, viscosity, surface tension, electrical conductivity and electrical transference, electrode potentials, diffusion, and vapor pressures. The silicate solutions at high

FIG. 10.
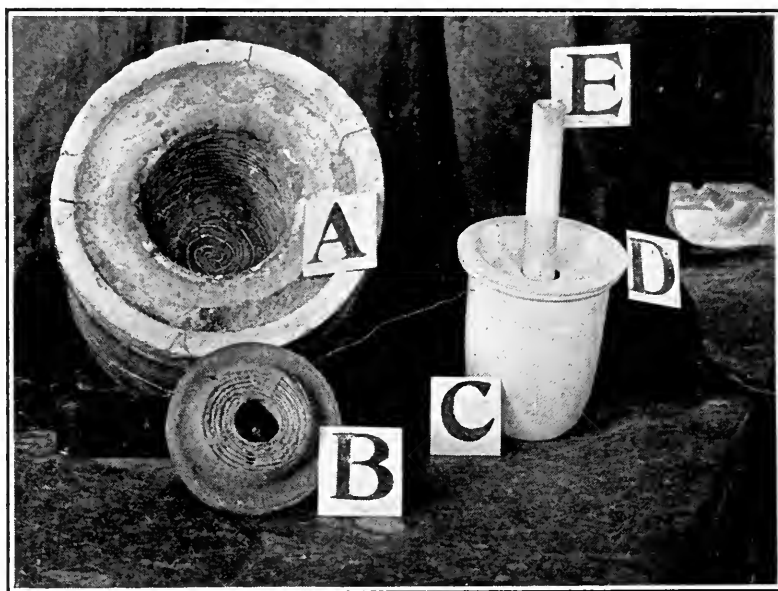
Showing the construction of the heating furnace of the viscosity apparatus.

temperatures are typical electrolytic conductors, and in this respect resemble most closely aqueous salt solutions. Some of the difficulties met with in measuring the properties of silicate solutions at high temperatures can perhaps best be appreciated by a brief consideration of the apparatus and methods which have been employed in measuring some of the above-mentioned properties.

Solubility of Gases.—Glass being a liquid, even at ordinary temperatures, should possess the property, characteristic of all liquids, of retaining in solution certain amounts of dissolved gases. The presence of this dissolved gas in ordinary glass can be made apparent by the following experiment :[3]

---

[3] *Univ. Ill. Eng. Exp. Sta. Bull.,* **18** (1921).

A piece of clear glass free from bubbles, such as that shown in Fig. 5, is placed in a porcelain pot and heated in the closed furnace shown in Fig. 6. When the glass has reached a high temperature

FIG. 11.
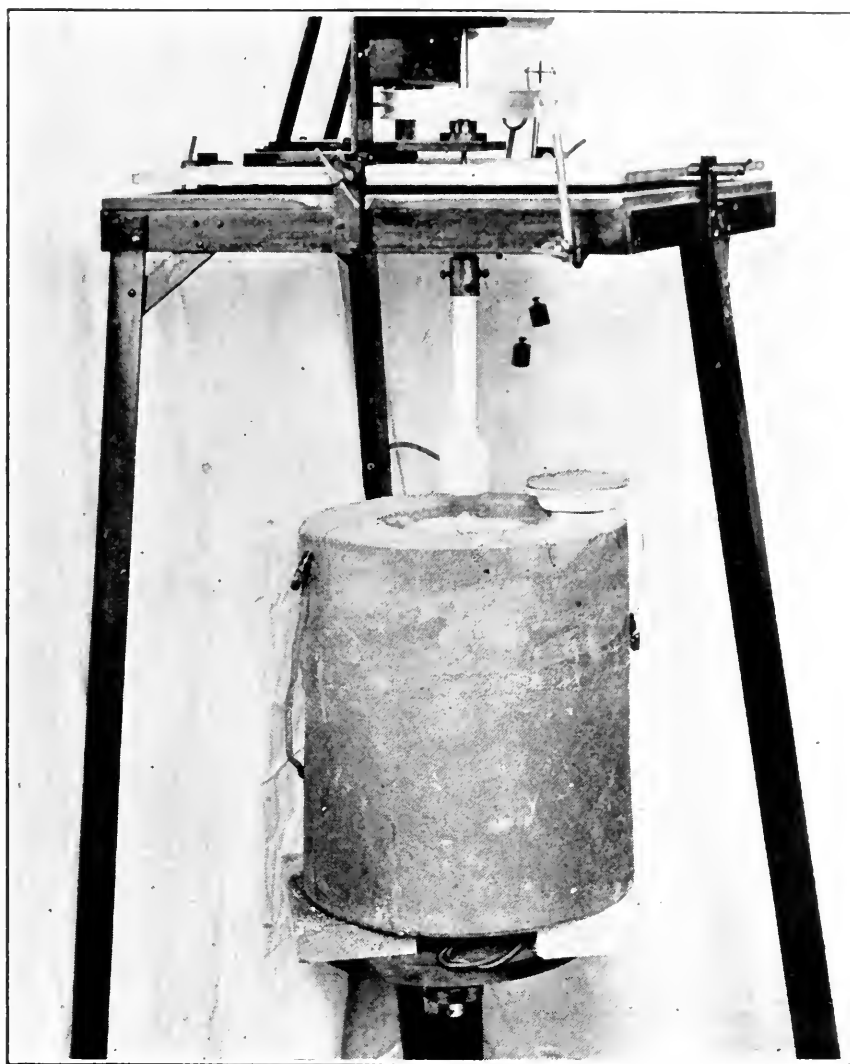
Showing set-up of the viscosity apparatus. After raising the furnace and pot of glass until the stirring cylinder is immersed to the proper depth, the cylinder is rotated by the two falling weights.

and is fairly fluid, the furnace chamber is suddenly connected to the large, previously evacuated tank shown in the figure, thus causing the pressure in the furnace to drop to a low value. Under these circumstances the gases in solution in the glass are immediately evolved, in much the same way as the carbon dioxide comes out of a bottle of soda water when it is opened. The behavior of the glass

is very similar to that of the soda water, it froths and foams vigorously, and after the experiment is over and the glass has cooled down, we discover on opening the furnace that practically all of the glass is found above the pot in the form of a solidified white foam, as shown in Fig. 7. By the use of the apparatus shown in Fig. 8 the above experiment can be carried out in such a way that the evolved gases can be conveniently collected, measured, and analyzed. Some of the results of such a quantitative experiment are shown in Table I.

Fig. 12.
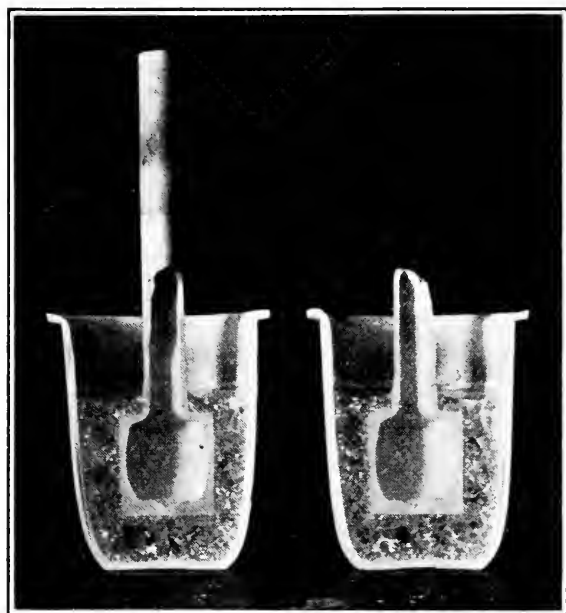
Cross-section of pot and stirring cylinder after completion of an experiment.

Viscosity.—The measurement of the viscosity of a viscous liquid at high temperatures is rendered difficult by the fact that owing to the presence of dissolved gases it is almost impossible to keep the liquid free from bubbles and consequently the customary method of measuring viscosity by the rate of flow of the liquid through a capillary tube is out of the question on account of the great difficulties involved. The presence of these bubbles also makes the adoption of any method depending upon the rate of fall of a sphere through the liquid, undesirable, owing to the fact that bubbles are likely to be picked up during the fall and to produce correspondingly erroneous results. About the only convenient, and at the same time reliable method which can be used for measuring

the viscosity of glass at high temperatures is the method of rotating cylinders which is illustrated by the apparatus shown in Fig. 9. The molten glass is contained in a cylindrical porcelain pot heated on the outside by a platinum heating coil (see Fig. 10). An inner hollow porcelain cylinder with a vertical connecting shaft is coaxial with the outer cylinder and is rotated by any suitable method which enables one to measure the speed of rotation and the power or force required to drive the inner cylinder in the molten

FIG. 13.

Glass No.	SiO_2	Na_2O	CaO
1	47.6	51.8	-
2	82.3	17.7	-
3	70.0	30.0	-
4	60.0	40.0	-
5	62.7	14.7	22.6
6	60.5	20.0	19.5
7	60.0	30.0	10.0
8	70.0	20.0	10.0
9	52.5	40.0	7.5
10	70.0	10.0	20.0
12	72.0	14.5	13.5

W/RPM = Stirring friction
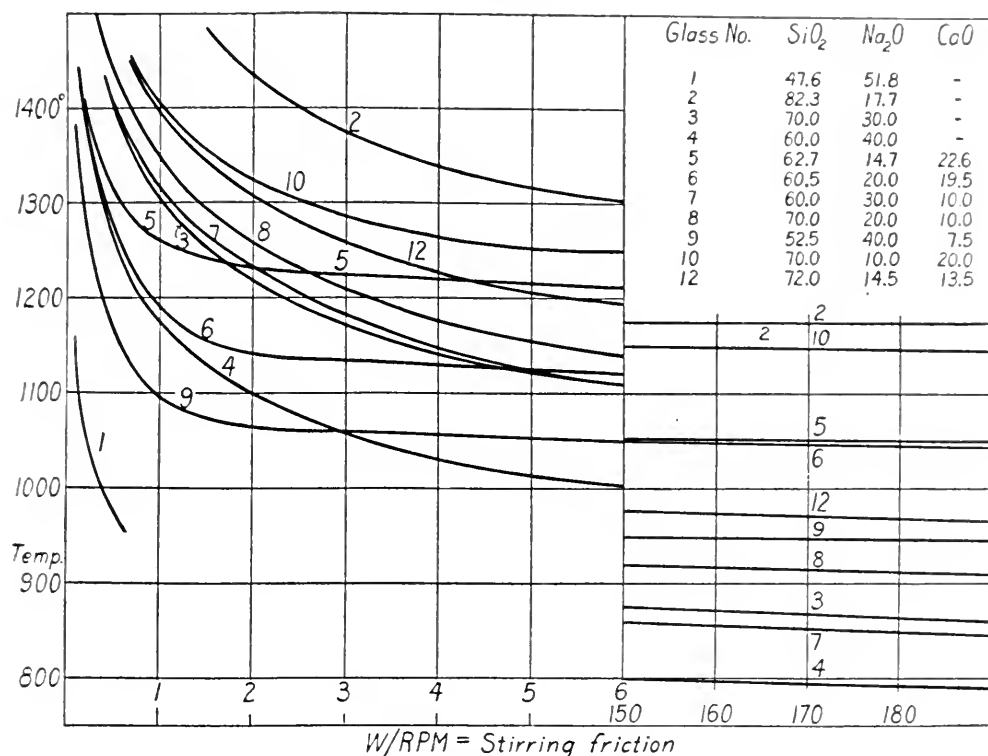
Temperature-viscosity curves. Viscosity expressed in terms of stirring friction.

glass at the speed in question. By determining these two quantities together with the constant of the apparatus, which is obtained by making a similar experiment with a liquid of known viscosity, the viscosity of the glass can be computed. In this way we have investigated at Illinois the complete viscosity-temperature relations for that region of the Na_2O-SiO_2-CaO system within which reasonably stable glasses can be obtained at temperatures below 1500°. The set-up of the apparatus employed in these investigations is shown in Fig. 11, while Fig. 12 shows a cross-section of a pot of glass after the completion of the measurements.

Fig. 13 shows the character of some of the temperature-viscosity curves obtained in this way for glasses of various compositions. By selecting a series of temperatures, and at each temperature reading off from the curves the corresponding viscosities of the various compositions studied, it is possible to prepare a diagram in which compositions are expressed by the usual

Fig. 14.
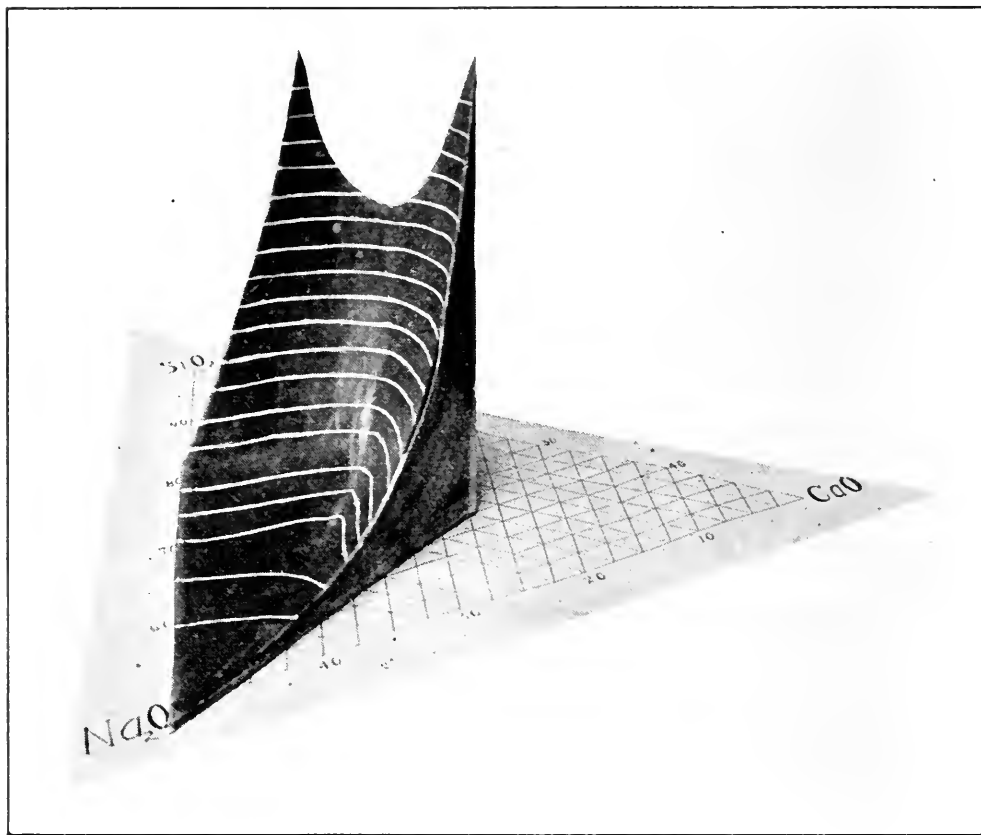
Model showing the viscosity surface at 1400°C.

triangular method and viscosities as the vertical ordinate. Fig. 14 shows a photograph of one of the solid models obtained in this way. The white lines on the model are *isokoms*, that is, lines of constant viscosity. Fig. 15 shows the composition diagram with the projections of the isokoms. From a complete set of diagrams, such as that shown in Fig. 15, one can evidently plot the complete viscosity-temperature curve for a glass of any composition lying within the region studied. In other words, one can read off the viscosity of

any such glass at any temperature within the temperature range employed in commercial glass manufacture.

Surface Tension.—In a manner similar to that employed in connection with the viscosity studies, a systematic study of the surface tensions of the same glasses is also being carried out, and the results will be expressed by diagrams of a similar kind. The apparatus and method employed are illustrated in Fig. 16. A precision of about 0.1 per cent. is obtained on the surface tension measurements. Preliminary results indicate that the surface ten-

FIG. 15.
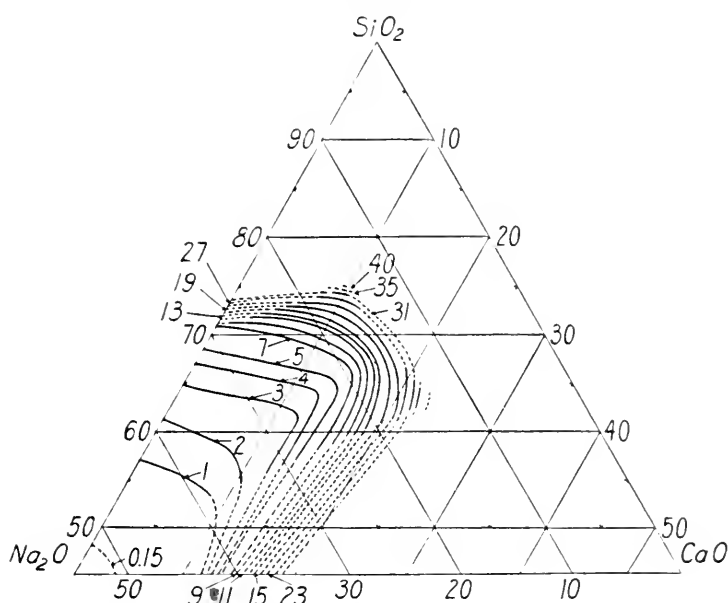
Isokoms (lines of constant viscosity) at 1400°C. in terms of stirring friction. These isokoms can be translated into poises by means of the standardization curve of the apparatus.

sion of soda-lime-silica glasses between 1200° and 1450° C. is in the order of magnitude of 100 dyne/cm.

Density.—A similar investigation of the density of the same glasses has been begun, using the principle of Archimedes. The apparatus employed is identical with that used in the surface tension measurements, except that the platinum cylinder is replaced by a small platinum sphere.

Electrical Conductivity.—A systematic investigation of the electrical conductivity of soda-lime-silica glasses has been planned, but no work on this problem has, as yet, been started.

V. HIGH TEMPERATURE CALORIMETRY.

The thermo-chemistry of ceramic systems at high temperatures is practically an unknown field, since no calorimetric methods for determining heat effects of slow reactions at high temperatures

FIG. 16.

Apparatus for measuring the surface tension of molten glass. The coiled spring measures the force with which the platinum cylinder is pulled into the glass surface. When approached from both directions the same equilibrium position is attained. The cylinder is standardized with liquids of known surface tensions.

have been devised. Owing to the lack of such data nothing whatever is known, for example, concerning the amount of heat absorbed by clay bodies during the process of firing. It

has been said with considerable truth that the clay-products manufacturer wastes such a large percentage of the heat which

FIG. 17.
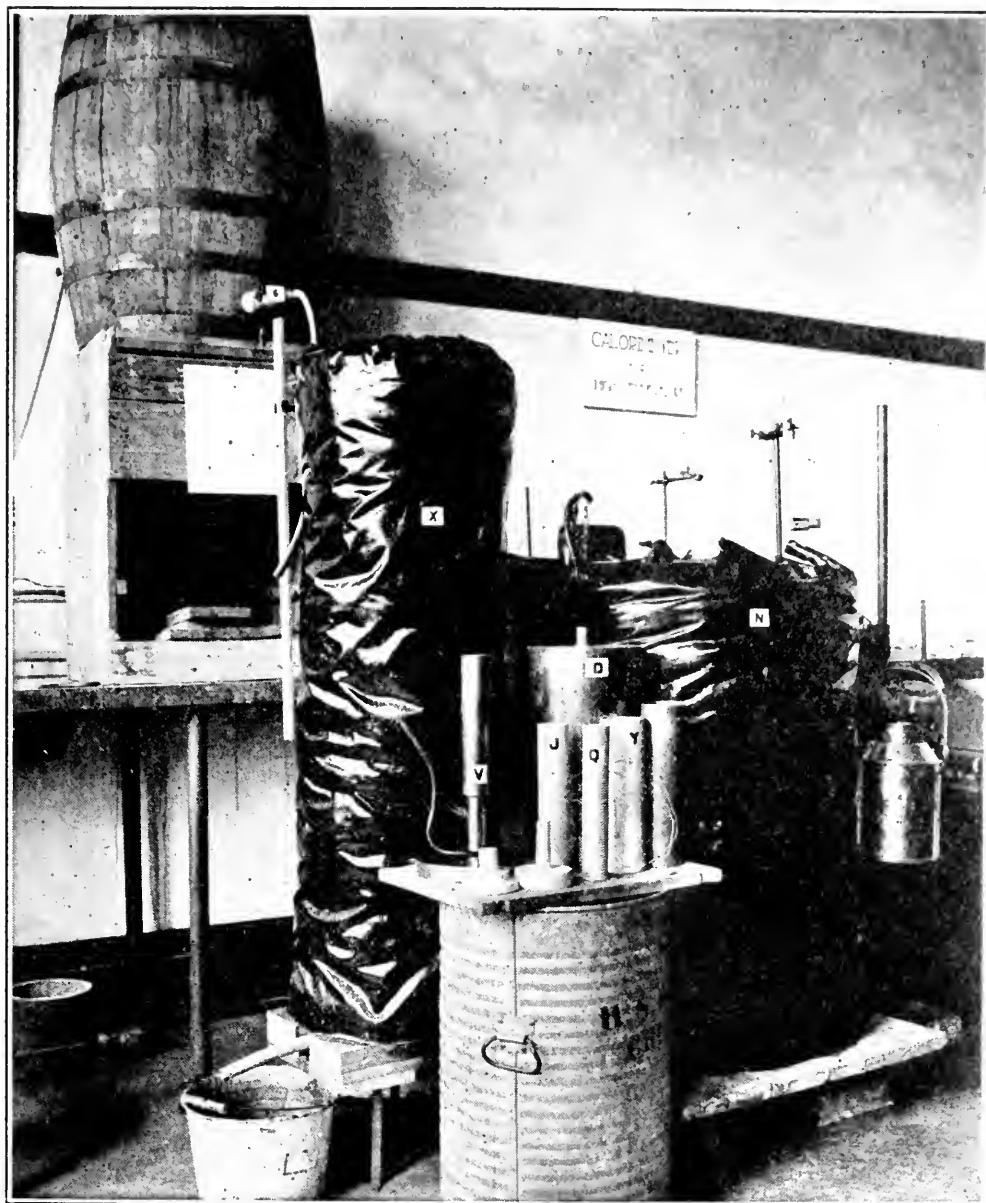
Apparatus for high temperature calorimetry.

he produces for the firing of his kilns, that he is not interested in knowing how much heat his ware must absorb before it is completely burned. While this is perhaps true as regards the total heat absorbed by a ware as fired in the older types of kilns, the kiln of

the future will be a much more efficient furnace, and it will be of interest to ascertain not only the total heat absorbed by the ware during burning, but also the way in which it is absorbed, that is, the amount which must be put into the ware in order to raise its temperature each 100° during firing operation.

In order to be able to measure the heat effects of the chemical and physical processes occurring at high temperatures we have devised at Illinois a calorimeter of the adiabatic type, the parts of which are shown in Fig. 17. The calorimeter consists essentially of an electrically heated alundum furnace tube Q, in which is placed

Fig. 18.
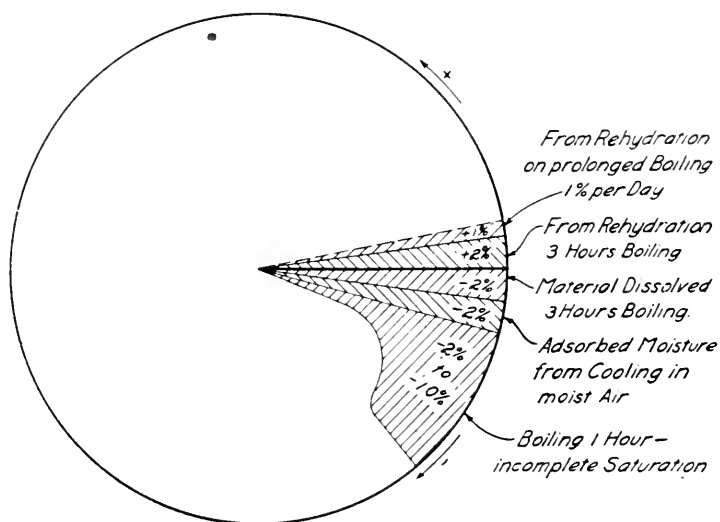
Indicating the nature and magnitudes of some of the sources of error in the "boiling-in-air" method of determining porosity.

the system to be investigated. The platinum heating wire on the furnace tube is protected by a second tube of alundum, J, and by a thin packing of calcined zirconia and finally by one or more glazed refractory tubes, Y, which function as radiation screens. The furnace tube itself, as well as the enclosing tubes, J, Y, are closed at the bottom and furnished with suitable covers at the top. This furnace is suspended within a polished nickel vessel, D, which can be evacuated, and this apparatus is then immersed in the water of the calorimeter, N, in a constant temperature room. The temperature of the water in the calorimeter is always kept the same as that of the room. The leads from the furnace heating coil and the leads for the necessary thermocouples are brought out through air-tight and water-tight connections through the cover, V.

The method of operation consists in passing a metered current of electricity through the heating coil of the furnace until the temperature of the system under investigation has become constant at

FIG. 19.
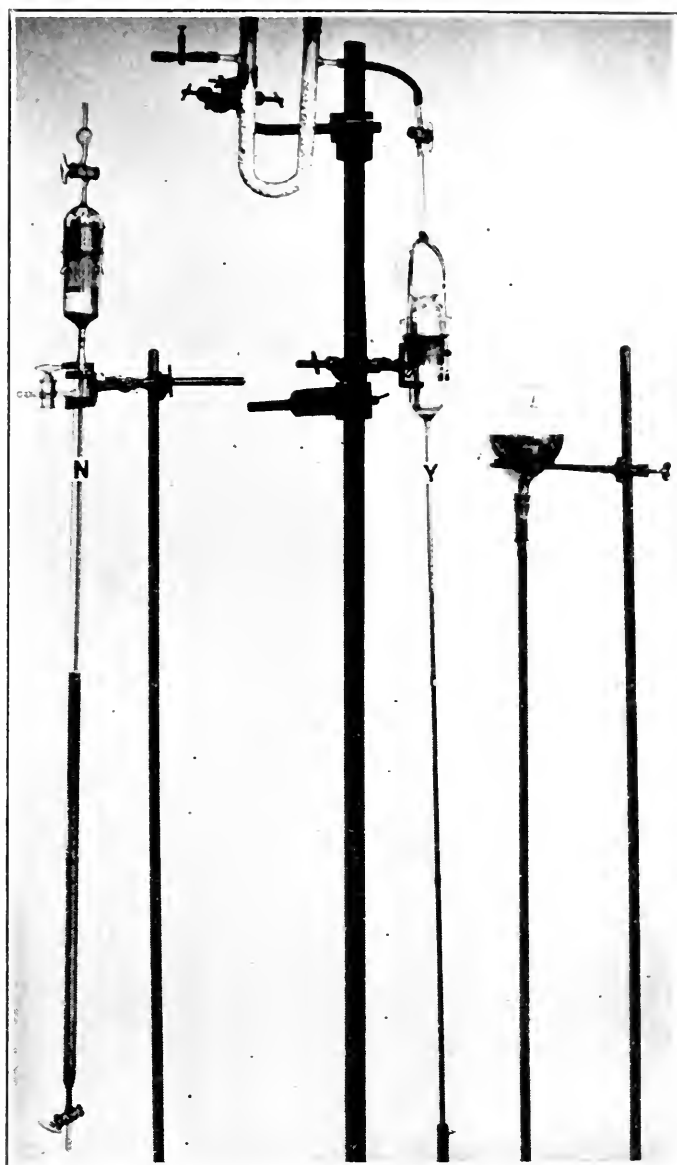
Washburn-Bunting Porosimeters.   N, general laboratory type; accuracy, 0.1 to 0.2 c.c. on pore volume, 0.05 c.c. on bulk volume, rapidity, about 3 minutes per determination. Y, McLeod-gauge type for vitrified porcelains; accuracy 0.01 c.c. on pore volume.

some desired value.   At the same time the high speed vacuum pump is kept constantly in operation maintaining a vacuum within the nickel vessel.   During the attainment of constant temperature within the furnace, a certain amount of the measured energy input

leaks out into the nickel vessel and is absorbed by the water of the calorimeter, thus tending to raise its temperature. In order to keep the temperature of the calorimeter constant, ice water at 0° is admitted through a valve, 6, the water in the calorimeter being thoroughly stirred meanwhile, and overflowing through a constant level outlet tube into a collecting vessel, 4. As soon as the temperature of the interior of the furnace has become constant, the electric meter is read and at the same time the collector under the overflow of the calorimeter is replaced by an empty one, and the rheostat is adjusted so as to give a larger current through the heating coil and to raise the temperature of the system under investigation to a new level, after which the same operations are repeated. By weighing the amounts of water which overflow from the calorimeter during each stage in the temperature rise, the amount of energy which leaks out of the furnace can be computed and by subtracting this from the energy input, the energy absorbed by the system and the furnace parts is obtained. The constant of the apparatus is determined by carrying out a second similar series of measurements with the furnace filled with a substance, such as quartz for example, whose heat absorption curve has been accurately determined over a wide range of temperature.

VI. STANDARD METHODS OF TESTING CERAMIC MATERIALS.

The services of the physical chemist or of the physicist and the chemist could be advantageously employed for the purpose of making accurate studies of the testing methods employed or proposed for any industrial material. In too many cases the testing methods in use have grown up more or less accidentally and have never been subjected to a thorough and critical examination at the hands of an expert chemist or physicist. The nature and magnitudes of many of the errors present are thus frequently unknown and the possibilities of improving the method, either in accuracy or convenience, or both, or of substituting perhaps a much better method of an entirely different nature, are therefore imperfectly known. The subject of physical chemistry has been built upon a foundation of accurate and careful quantitative measurements of great variety and the physical chemist therefore has the training and knowledge necessary to intelligently criticize testing methods which, after all, are always methods of measurement of some kind.

In order to illustrate the value of a scientific study of testing

methods we undertook at Illinois a critical examination of the methods employed for determining the porosity of ceramic bodies.[4] Porosity is customarily measured by filling the pores of the body, more or less completely, with some liquid and weighing the amount of liquid thus introduced. In order to ascertain the factors which control the rate at which a liquid penetrates small pores, it was found necessary to first develop the laws governing the dynamics of capillary flow. An investigation of the literature apparently showed that this subject had never received any attention, although the statics of capillarity has been, of course, very fully investigated. The laws which were thus derived [5] consisted of quantitative relations connecting the degree of penetrance of a porous body of a liquid, with the time of soaking, the size and length of the capillaries and the surface tension and viscosity of the liquid. The theory indicated that for bodies with very small pores, complete filling of the pores by any liquid could not be effected in any reasonable time without the aid of high vacuum and high pressure equipment. This conclusion was confirmed by experiment. With clay bodies certain other sources of error were also discovered and studied. The nature of some of these is indicated in Fig. 18.

A new method, in which a gas instead of a liquid is employed as the pore filling agent, was finally developed together with a suitable apparatus (Fig. 19) and by means of this method and apparatus it is now possible to carry out porosity determinations far more rapidly, conveniently and accurately than was possible by the method of liquid absorption. The results of this study illustrate some of the possibilities of improving testing methods which may come from a treatment of the method itself as a physico-chemical problem.

On a New Optical Property of Biaxial Crystals. C. V. RAMAN and V. S. TAMMA, India. (*Phil. Mag.*, March, 1922.)—It may be true that "Scientia non scit patriam," but it remains an observed fact that a certain flavor of the soil clings to the work in physics done in each land. The growing school of Indian physicists have taught us to expect in their papers either a different point of view or some subject of investigation that lies apart from those in the prevailing fashion.

[4] *Jour. Amer. Ceram. Soc.*, **4**, 916, 961, 983 (1921); **5**, 48, 112 (1922).

[5] *Phys. Rev.*, **17**, 273 (1921).

"The incandescent filament of a tiny 2-volt lamp or an illumi-nated pin-hole serves as a suitable source of light. At some distance from it is placed a crystal of aragonite cut and polished with parallel faces at right angles to the bisectrix of the acute angle between the optic axes. On suitably orienting the crystal and examining the pencil of light that has passed through it, a real, erect, unpolarized image of the luminous filament may be easily picked up and traced continuously away from the crystal for a considerable distance. The image is sharp and bright and practically achromatic if the object and the place of observation are both within a few centimetres of the crystal, one on each side.

"It should be remarked that these optical images formed by an aragonite plate differ from those formed by an ordinary converging lens in several respects. The images in the present case are real, erect, and of unit magnification irrespective of the distance of either object or image from the crystal. Further, the image is continuous, that is, it may be observed anywhere in the prolongation of a certain line for a considerable distance from the crystal and not merely at a single point as in the case of images formed by a lens. Also the images appear sharply defined in a field of diffuse light, showing that only part of the energy passing through the crystal is brought to a focus. The object being fixed, the image moves when the orien-tation of the crystal is altered, but not when the plate is moved in its own plane. The focussing property, in other words, appears to be related to a fixed direction within the crystal. In order that the image may be within the field of observation it is necessary, in fact, that the bundle of light-rays should pass through the crystal roughly in this fixed direction, which appears to be that of either axis of single ray velocity in the crystal." G. F. S.

The Motion of Electrons in Argon. J. S. TOWNSEND and V. A. BAILEY. (*Phil. Mag.,* March, 1922.)—A few months ago these Oxford workers published an account of the motion of electrons in oxygen, nitrogen and hydrogen, and showed how to calculate the mean free path of the electron and its loss of energy upon colliding with a molecule. The same methods are now applied to argon and rather surprising conclusions are reached. "Thus when an electron moving with a velocity of the order of 10^8 centimetres per second collides with a molecule of argon it loses about one ten-thousandth part of its energy, but when it collides with molecules of the other gases it loses more than 1 per cent. of its energy. Also the mean free path of an electron moving with these velocities in argon is about ten times as long as its mean free path in the other gases at the same pressure." Whatever in argon may cause the long free path, it cannot be the small diameter of its molecule, for they are smaller than those of nitrogen and larger than those of hydrogen.

G. F. S.

RECENT ADVANCES IN APPLIED ELECTROCHEMISTRY.*

BY

MAURICE DE KAY THOMPSON, Ph.D.

Department of Physics, Massachusetts Institute of Technology.

APPLIED electrochemistry consists of the following rather diverse subjects:

(1) Electroplating and galvanoplastic processes, such as electrotyping; (2) wet electrometallurgy; (3) the electrolytic production of chemical compounds in aqueous solutions; (4) primary and secondary cells; (5) electric furnace products, and the furnaces in which they are made; and (6) gas reactions produced by electricity.

It may be well, first, to explain what will be considered advances in this applied science. There may be differences of opinion on this point, but it will here be considered that an increase in the quantity or improvement of the quality of an electrochemical product, an improvement in method, apparatus, or efficiency of production, or the extension of electrochemical methods to new products, would all be advances.

Electroplating and electrotyping are the earliest industrial application of electricity, and were practiced before the invention of the dynamo machine. Originally electroplating was confined largely to the deposition of gold and silver for decorative purposes, but it has developed more and more into use as a means of depositing protective coatings. If it is also pleasing of appearance, so much the better, as in the case of nickel plating, which was first developed in this country. A recent improvement in nickel plating consists in the use of nickel fluoride in place of nickel chloride or sulfate, because the fluoride gives a finer grained deposit with higher tensile strength and greater hardness.[1] This is another example of the familiar fact that the quality of the deposit of metals depends to a large extent on the salt from which it is deposited.

---

* Presented at the Stated Meeting of the Institute held Wednesday, March 15, 1922.

[1] Blum, *Tr. Am. Electroch. Soc.* for 1921.

We usually think of nickel as a bright silver metal, but it may be plated from certain solutions, as a black deposit. A solution giving black nickel contains nickel and zinc sulfates, cyanide, arsenious acid, ammonia, and ammonium carbonate. This black nickel was used extensively during the war for hardware, harness fittings, and equipment used by the government requiring a dark

FIG. 1.
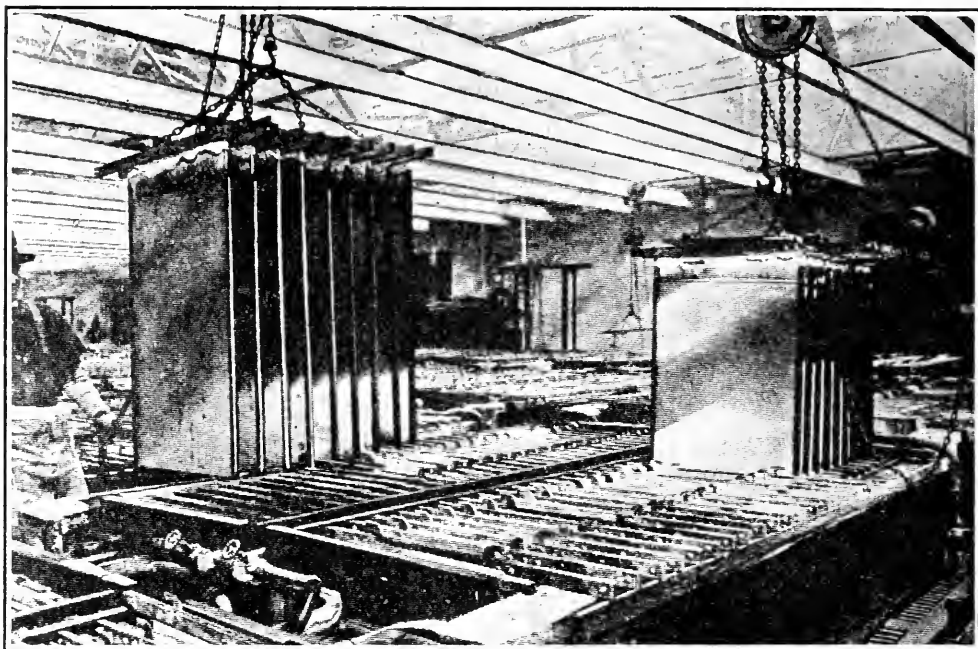
Electrolytic zinc plant; drawing zinc. Great Falls Reduction Department. Courtesy Anaconda Copper Mining Company.

finish.[2] It may be mentioned in passing that other metals also may be deposited black, *e.g.,* silver, copper, and platinum.

Within recent years zinc and lead have been used extensively for electroplating, especially in the preparation of military supplies. Electroplated zinc has a dull finish which detracts considerably from its appearance compared with ordinary so-called galvanized coatings which are formed by dipping in melted zinc, but they give much better protection. Lead plating has recently been conducted on an extensive scale for lining gas shells and also for plating on the inside of underweight shells merely to increase the

[2] Blum, *Tr. Am. Electroch. Soc.,* **34,** 169 (1919), "Electroplating for Military Uses."

weight, thus salvaging thousands of rejected shells. Other applications such as the lining of chemical apparatus are under investigation, and it is probable that lead plating will be more extensively used in the future. A solution of lead fluosilicate or borate is used.

Until very recently the electrodeposition of alloys was confined

FIG. 2.
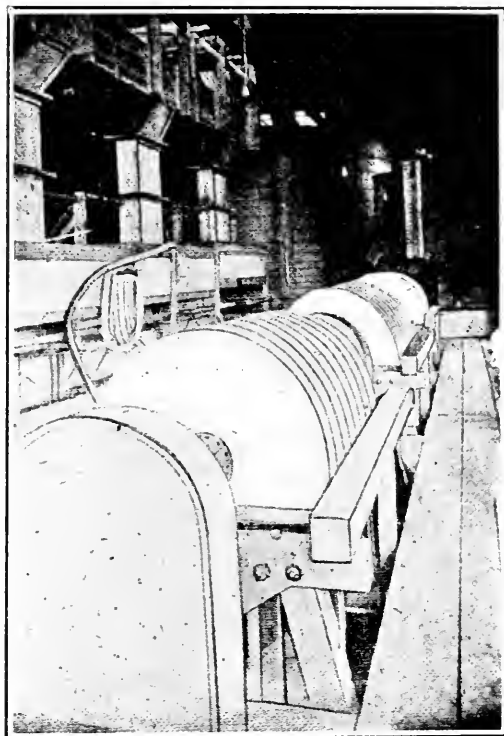
Cadmium cells, showing rotating cathodes
in place.

principally to electroplating brass. Since zinc and copper, the constituents of brass, have electrolytic potentials far apart in value, it is necessary to use a solution in which the potentials are brought near together. A very complex salt is required, and cyanides are the only ones which give satisfactory deposits of brass.

One of the most recently adopted alloy deposits consists of equal parts of tin and lead. These two metals are so nearly equal in their electrolytic potentials that there is no trouble at all in depositing them together from solutions of their simple salts. In fact, tin cannot be separated from lead by electrolytic refining. The solution is a mixture of lead and tin fluosilicates or fluo-

borates. This lead-tin deposit is used for the lining of air flasks of naval torpedoes.

Other improvements in electroplating have to do with the cleaning of the surface in preparation for plating, this being a most important step in the process. One such method consists in simultaneously cleaning and plating with copper from a hot cyanide bath.[3] The hot alkaline cyanide solution removes the dirt and, wherever clean, a good copper deposit is produced by the current. Another method is to electrolyze as cathode in a hot alkaline solution. The hydrogen evolved reduces oxides and helps to carry off dirt. The scale from sheet iron plates may be removed by electrolyzing as cathode in a hot sulfuric acid reducing the scale to iron in place of blowing it off with hydrogen as is done in ordinary pickling. This would seem to be a much better method of removing the scale than pickling in hot sulfuric acid, which uses up a large quantity of iron and acid.[4] This process is reported to be in use. A rather interesting method of covering aluminum wire for the purpose of insulation may be mentioned here as it is closely related to plating. It has long been known that aluminum electrolyzed as an anode in nearly any solution is soon covered with a thin non-conducting layer of some aluminum compound. In recent years use has been made of this property of aluminum for insulating aluminum wire. The wire is drawn through a sodium silicate solution in which it is electrolyzed as an anode.[5] The thin film produced will stand 200 to 500 volts. This wire is used in coils which require light weight and which are subject to relatively high temperature. Its advantage is the small volume taken up by the insulation.

There have been only a few innovations in electrotyping. The usual procedure is to take an impression in wax and to deposit the metal to be used in printing on this after making the surface conducting with graphite powder. While this is satisfactory for some purposes, it is not sufficiently exact to make substitutes for the steel plates used by the government in engraving bond issues. Such plates, however, have been successfully produced by substituting

[3] *Tr. Am. Electroch. Soc.*, **27**, 141 (1915).

[4] Hering, *Met. Chem. Eng.*, **13**, 785 (1915); also *Tr. Am. Electroch. Soc.*, **31**, 181 (1917); and *Met. Chem. Eng.*, **17**, 713 (1918).

[5] German Patent, 238,110 (1912); U. S. Patent, 1,289,215; Skinner and Chubb, *Tr. Am. Electroch. Soc.*, **26**, 137 (1914).

for the wax, negatives made by electrodeposition of alternate layers of nickel and copper on the steel engraving to be copied, stripping this from the engraving and then depositing the actual printing plate on this metal negative.[6] The surface must be slightly greased so that the two metal sheets can be separated. The printing plate is made by a deposition first of nickel, .005 inch thick, and then copper and nickel in alternate layers for periods of one hour during six days. Among other galvanoplastic products, more

FIG. 3.
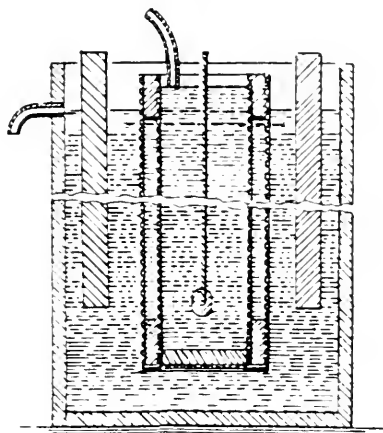
Hybinette vat for nickel deposition. Nickel sulfate solution circulates to cathode in the diaphragm through diaphragms by the nickel-copper anodes and out the overflow.

or less recent, may be mentioned duplicating phonographic records, all the metal decorations on glass and pottery, and the production of bronze statues.

Finally, many soldiers whose faces were disfigured during the war were supplied with artificial faces of thin copper plated on plaster models made from photographs. These copper faces were painted, of course, to look like the original.

In recent years there have been some notable advances in wet electrometallurgy. Numerous early attempts to extract metals from their ores by methods involving electrolysis ended in failure. Among these may be mentioned the Marchese [7] process, where the attempt was made to produce pure copper by electrolyzing copper matte anodes. The curious thing about the history of this process

---

[6] Blum, *Tr. Am. Electroch. Soc.*, **39**, Oct. (1921).
[7] *Z. f. Electroch.*, **1**, 50 (1894).

is that the laboratory tests were considered encouraging, and the process failed when tried on a larger scale.

The history of the Siemens process for copper is very similar. The Hoepfner processes for copper[8] and for zinc[9] extraction also failed. The first success of this kind was achieved at Chuquicamata,[10] where copper ore is leached in sulfuric acid, and

Fig. 4.
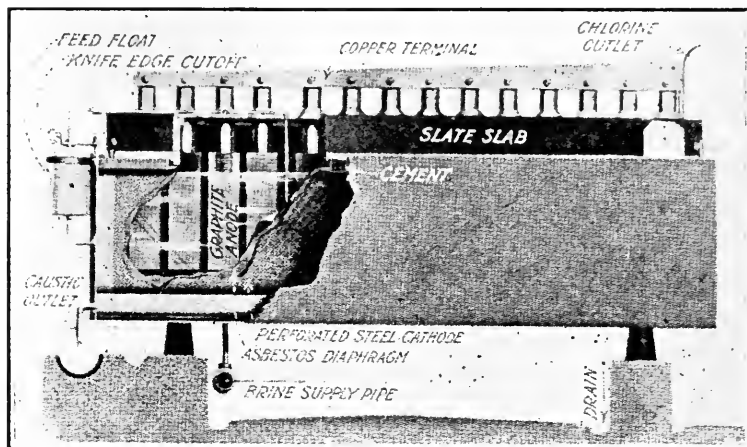
The Nelson cell for making sodium hydrate and chlorine.

pure copper is deposited electrolytically, using unattackable anodes of fused magnetite or duriron (an alloy of iron and silicon) and copper cathodes. Practically the same process has been extended recently to the extraction of zinc,[11] by depositing zinc from very pure zinc sulfate solutions. Production of electrolytic zinc in quantity began in 1916. A very pure solution is required and some elements must be reduced to about one milligram per litre. Cobalt and chlorine cause the most difficulty. In this case lead anodes may be used, and the cathodes are sheets of aluminum. At first, in some plants, the cathodes were rotated, but stationary cathodes are now universal. The zinc is stripped from the cathodes every 48 hours and remelted. The current density is 25 amperes a square foot. In 1920 there were four plants in this country and one in

[8] *Z. f. angew. Chem.,* p. 160 (1891).

[9] *Metall. u. Erz.,* **10,** 206 (1913).

[10] Capelen-Smith, *Tr. Am. Electroch. Soc.,* **25,** 193 (1914).

[11] Ingalls, *Tr. Am. Electroch. Soc.* for 1921; Hofman, "Metallurgy of Zinc and Cadmium," 1922.

Canada producing electrolytic zinc, one in Australia and two in Tasmania.[12] The production in this country is about 10 per cent. of the world's pre-war production.

Cadmium is a metal which occurs only in small quantities in its ores, and production is profitable only where it is a by-product. An electrolytic method for recovering cadmium has been developed

FIG. 5.
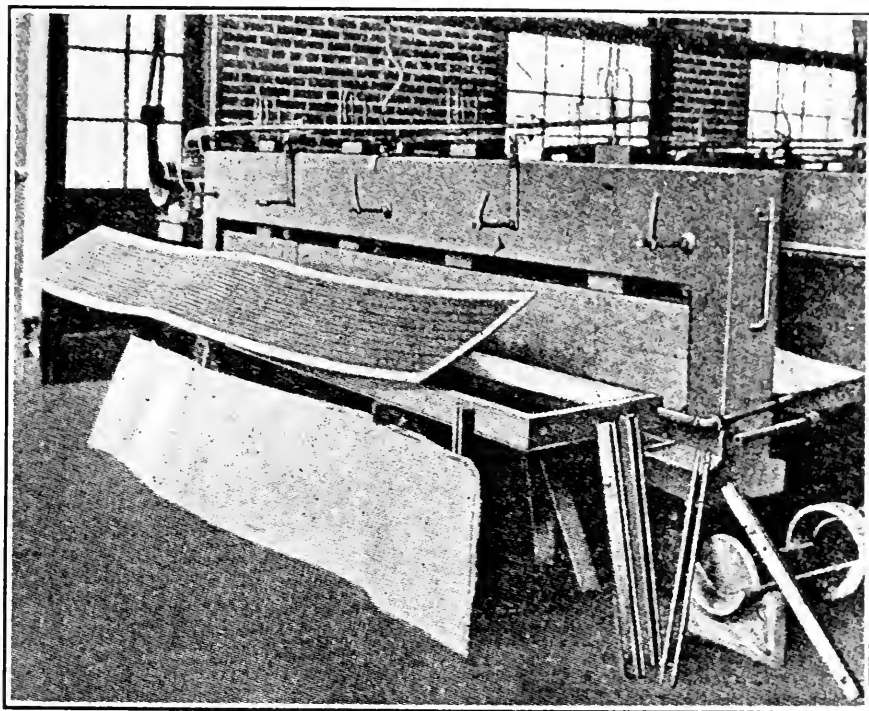
The Allen-Moore cell for making sodium hydrate and chlorine.

recently at the mammoth Electrolytic Zinc Plant of the U.·S. Smelting, Refining, and Mining Company at Kennett, California.[13] In purifying the zinc solution for electrolysis, copper and cadmium are precipitated by zinc dust. This precipitate has the appearance of a black mud. It is dissolved in dilute sulfuric acid, leaving the copper behind, and is then precipitated on zinc sheets by cementation. This is dissolved in acid cadmium electrolyte, iron and thallium are removed, and the solution is electrolyzed on the rotating aluminum cathodes from which it is stripped. Its

---

[12] Keeney, *El. J.*, **17**, 206 (1920).

[13] Hanley, *Chem. Met. Eng.*, **23**, 1257 (1920).

uses are as a pigment when changed to the sulfide, and in the metallic state for low melting point alloys.

The following problem is a little different from either recovering metals from ores or refining. This consists in separating the constituents of a copper-nickel alloy. Many ores contain these two metals in about equal amounts, and the smelting process gives

Fig. 6.
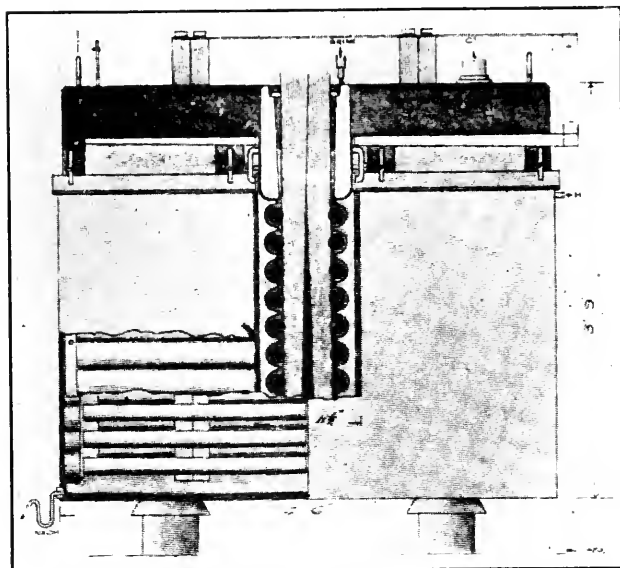
The Marsh cell for making sodium hydrate and
chlorine.

an alloy of about equal parts. An earlier electrochemical process, due to David H. Brown,[14] accomplished this separation, but a more recent method is the Hybinette [15] process, originating in Norway, and now in use in Canada. In this process the anodes are not unattackable, as in the case of the copper and zinc recovering processes just menioned, but consist of the alloy of nickel, copper and iron. The cathode is a thin sheet of copper or iron with the surface treated so the nickel can be stripped off, and is separated from the anodes by a diaphragm of two sheets of cloth. The nickel sulfate solution circulates to the cathode compartment. This causes a flow through the diaphragm and overcomes the

[14] *Z. f. Electroch.,* **9,** 392 (1903).
[15] *Electroch. Met. Ind.,* **4,** 34 (1906) ; *Met. Chem. Eng.,* **13,** 249 (1915); *Mining Sci. Press,* **114,** 666 (1917).

migration of the copper which is dissolved with the nickel at the anode. The solution from the anode compartment is passed over pure nickel, causing the copper to precipitate, and this solution circulates to the cathode.

The refining of metals by electrolysis is one of the largest of the electrochemical industries. The principal metals refined electrolytically are copper, nickel, gold, silver and more recently lead, tin, and iron. The production of electrolytic iron was started in this country five years ago, by the Western Electric Company for making iron powder.[16] Their plant at Hawthorne, Illinois, produces 25,000 pounds a week. On account of its brittleness, it is easily ground. The anodes are mild steel and the cathodes polished steel, from which the deposited metal is stripped when it has become ⅛ to ¼ inch thick.

The electrolytic refining of tin was begun in 1916 at Perth Amboy.[17] Originally fluosilicate solution was used, but later it was changed to sulfate of tin.

It occasionally happens that electrochemical methods are given up in favor of purely chemical ones, as in the detinning of scrap. Up to 1907 the caustic soda detinning process dominated the entire field. In this process the tin scrap was packed into iron gauze baskets and electrolyzed as anode in a caustic soda solution with sheet iron cathodes. The tin dissolved, and deposited in a spongy form on the cathode. It was a very troublesome process to operate on account of the close attention required by the electrolyte, and has been replaced to a great extent by the chlorine process.[18]

The most important process in the production of chemical compounds or elements by electrolyzing aqueous solutions is the electrolysis of sodium chloride with a diaphragm separating the anode from the cathode, for the production of sodium hydrate and chlorine. Many cells have been devised for this purpose. Chlorine is a gas and comes out of the cell of itself, but the hydrate must be removed by continuously drawing off the cathode solution. If the hydrate is drawn off too rapidly, the solution will be too dilute, while if the concentration

[16] Stoughten, *Chem. Met. Eng.,* 26, 128 (1922) ; *J. Am. Inst. E. E.,* 50, 596 (1921).

[17] *Tr. Am. Electroch. Soc.,* 38, 163 (1920).

[18] *Met. Chem. Eng.,* 17, 187 (1917).

of hydrate becomes high, the hydroxyl irons migrate to the anode compartment, form chlorate, and attack the graphite anodes. In designing an alkali-chlorine cell, the object is to get the hydrate out just as soon as the desired concentration at the cathode can be produced. It was soon found that a good way to accomplish this was to have the cathode made tight against the diaphragm, and have no liquid in this compartment except what filters through from the anode compartment. The electrolyte decomposed at the cathode is thus washed away soon after decomposition. This was done first in the Hargreaves-Bird cell. The Nelson [19] and the Allen-Moore [20] cells, both of recent design, depend on the same principle as the Hargreaves-Bird cell, but differ in construction details. A still later construction of the same type is the Marsh [21] cell, in which the anode and cathode are brought closer together by using graphite rods for anodes with correspondingly fluted cathodes, saving both power and floor space. Another method of removing the alkali is used in the Basel cell,[22] introduced in France during the war. In 1917 these cells were producing nearly half of the total French output of chlorine. In this cell the " propulsive " cathode is placed in a comparatively narrow cathode chamber formed by narrow meshed asbestos fabric. The hydrogen liberated in this small chamber produces in the surface of the electrolyte a froth consisting of bubbles of hydrogen, the shells of which consist of solution of alkali carried up by the gas. This froth is carried away through an overflow.

In most electrochemical processes for producing chemical compounds the substance to be acted on is in solution and unattackable anodes are used. The following are two examples where the anode furnishes one of the elements going into the product. A number of years ago the Luckow process for white lead was invented, consisting in electrolyzing lead anodes in a solution of potassium chlorate and carbonate, blowing in a mixture of air and carbonic acid to replace the carbonic acid used up. This, or a similar method, was referred to in 1920 in one of the technical journals [23] as having been the subject of a successful research made for the

[19] *Tr. Am. Electroch. Soc.*, **35**, 239 (1919).

[20] *Chem. Met. Eng.*, **21**, 370 (1919).

[21] *Tr. Am. Electroch. Soc.*, Vol. 39 (1921).

[22] *Chem. Met. Eng.*, **24**, 168 (1921).

[23] *Chem. Met. Eng.*, **22**, 531 (1920), Editorial.

purpose of starting this manufacture in this county, and it is probably now in operation.

During the war there was urgent need for neutral solutions of sodium permanganate. The chemical method of making this is to heat manganese dioxide with sodium hydrate, dissolve the manganate formed and then oxidize to permanganate either by electrolysis in the anode compartment of an electrolytic cell or by means

FIG. 7.
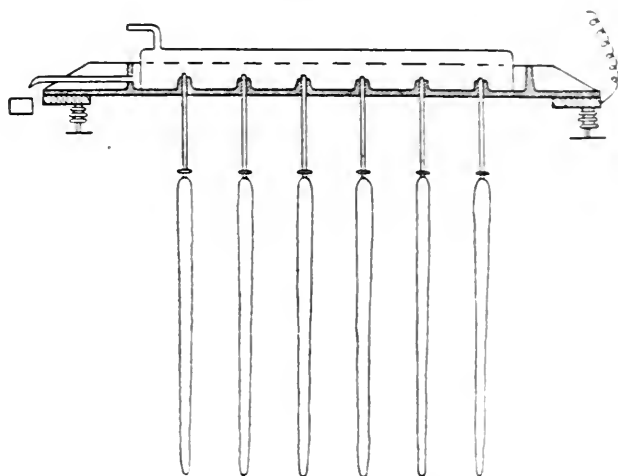
Basel cell cathode unit.

of chlorine or carbonic acid. This was not even as satisfactory as the same method for potassium permanganate, as the yield of sodium manganate on roasting the dioxide of manganese with sodium hydrate is less than the corresponding reaction for the potassium compound, and that has a rather low efficiency. It had been known for a number of years that a ferro-manganese anode electrolyzed in potassium hydrate or carbonate gave a solution of potassium permanganate,[24] but it had not been tried on a large scale. This was done, however, nearly to the point of production, before the Armistice. The anodes were 75 per cent. ferro-manganese, separated from the iron cathode by a diaphragm. Of course, pure manganese would work better than ferro-manganese but this would be too expensive. The principal difficulties were with the anode. They are brittle and could not be cast in large plates because they invariably cracked on cooling, but must be cast

[24] Lorenz, Z. f. anorg. Ch., 12, 393 (1896).

Vol. 193, No. 1158—55

in bars, a number of which are clamped to an iron piece to form one complete anode. Then some difficulty was found with the tendency ferro-manganese has of becoming covered with an insulating layer of oxides when electrolyzed, but this may be largely overcome by keeping the temperature down. The current efficiency is only about 35 per cent. This low efficiency is due to the fact that part of the current is used to oxidize the iron and only part of the manganese is changed to permanganate.

The process works equally well for potassium permanganate.[25]

The production of organic compounds by electrolysis has had relatively little application in this country, although in Germany a number of compounds such as iodoform, chloral, vanillin, azo and hydrazo compounds and anthraquinone have been manufactured profitably. During the war, however, the impossibility of getting photographic developers from Germany caused the Eastman Kodak Company,[26] among others, to experiment on the electrolytic production of paraminophenol by electrolyzing nitrobenzene suspended in sulfuric acid solution, this having long been known as a laboratory experiment. Four men and 50 cells produced 80 to 100 pounds a week, but it was found too expensive to compete with any chemical process, and was abandoned. The plant was converted to the production of ammonium persulfate when this was in demand by the government.

On the other hand, another company is now manufacturing anthraquinone electrochemically, and it is expected that the electrolytic manufacture of paraminophenol, hydroquinone, and other compounds will be started soon.[27]

It is rumored that in Germany aniline is made by introducing nitrobenzol in the cathode compartment of alkali-chlorine cells. This has two beneficial effects: It saves the evolution of a corresponding amount of hydrogen which is usually wasted, and lowers the cell voltage by depolarization.

Storage batteries and primary batteries have had no very striking developments. The iron clad battery, now about ten years old, is one of the most radical departures in pasted plate storage batteries. The positive lead peroxide plate is the weak part

[25] See *Tr. Am. Electroch. Soc.*, **35**, 371 (1919) ; *J. Ind. Eng. Ch.*, **13**, 763 (1921) ; *Chem. Met. Eng.*, **21**, 680 (1919).

[26] *Tr. Am. Electroch. Soc.* for 1921.

[27] Note from Dr. Thatcher of the Kathol Mfg. Co.

of these batteries on account of shedding in the material. In the so-called iron clad battery the positive plate is made by packing lead peroxide in a vulcanite tube perforated with small openings for the passage of the current. A rod of lead runs through the centre of each tube for contact. These positives have a longer life than the ordinary pasted plate. A battery is now made by the Philadelphia Storage Battery Company in which the peroxide plate is protected from shedding by slotted rubber containers, and for which a life as long as that of the iron clad battery is claimed. Within a year a very thin plate battery giving 50 to 200 per cent. higher output per unit weight and with a longer life has been described by C. W. Hazlett.[28] A further advantage of plates only $1/_{32}$ of an inch thick, as are used in this battery, is that they are so assembled as to make buckling impossible.

Until recently all pasted plates have been filled by hand, using wooden paddles to force the lead oxide paste into the lead-antimony grids. Of late, some manufacturers have developed a machine for this purpose.

The most important primary batteries are Leclanché cells with very little electrolyte, called dry cells. They are used for ignition, flash lights, telephones, and all kinds of open circuit service. Millions of them are made a year in this country. There are two drawbacks to these cells: They are apt to deteriorate even when not in use, and when in use, if too much current is drawn at once, they polarize, as the depolarizer, manganese dioxide, is not very rapid in action. The manufacturers are constantly working to improve this battery, but the results are in general kept secret. One method that has been adopted by some to prevent deterioration before putting in service is to make up the battery perfectly dry [29] and have the necessary water added when it is put in service. A recent French modification is to do away with the manganese dioxide entirely, and use porous carbon in its place, which takes up the oxygen of the air and makes this available for depolarization. This depolarizer is said to be permanent.[30]

There has been important progress during the last few years in electrolyzing fused salts. The largest in these industries, the

---

[28] *Tr. Am. Electroch. Soc.* for 1921.

[29] *Electrician*, **83**, 605 (1919).

[30] *C. r.*, **172**, 317 (1921).

production of aluminum, increased considerably in quantity during the war, and aluminum is now fourth of the non-ferrous metals as to quantity produced, the order being copper, zinc, lead, aluminum. During the last few years magnesium and cerium were made in quantity for the first time in this country. Calcium production was also started in small amounts, as there is not much demand for this metal in the pure state, but an alloy of lead, calcium, and barium known as Frary metal, is now produced in large quantities for a bearing metal, by electrolyzing a mixture of fused calcium and barium chlorides on a fused lead cathode contained in iron pots.[31] The layer of fused salt is 3 to 4 inches thick. The anode is a graphite rod at the centre. The pots are placed in brick-work fired with coal for melting the lead, and the salt mixture is fused by the passage of the current. There is a tendency towards forming metal fog and calcium and barium carbides, so that three days' electrolysis is required to produce an alloy containing 2 per cent. of the alkaline earth metals. When the proper amounts of calcium and barium have been electrolyzed into the lead, the alloy is drawn off from a whole series of pots and mixed in a large kettle and further alloyed ingredients are added, such as $\frac{1}{4}$ per cent. of mercury.

Practically all metals made by electrolyzing fused salts are made from a solution of the oxide in some fused salt or from the fused chloride of the metal. In the manufacture of aluminum, aluminum oxide is dissolved in a mixture of fluorides, held in a carbon cell at about 1000° C. The carbon container is the cathode, and graphite anodes are used. Aluminum is collected at the bottom and is removed from time to time. Magnesium is made by the more generally used process of electrolyzing the fused chloride. Magnesium floats in the bath and is ladled out with an iron spoon.

In electrolyzing calcium chloride the metal would burn up if allowed to float around on the surface of the chloride, so it is removed as rapidly as it is produced by allowing it to freeze to the cathode which dips only a short distance into the chloride. The cathode is gradually raised and thus a stick of calcium is drawn out of the bath.

The electrolysis of fused salts is in principle very simple, but just the right conditions have to be found before it can be carried

---

[31] *Tr. Am. Electroch. Soc.* for 1921.

out successfully, and these are different for each metal. There are also numerous phenomena that appear in the electrolysis of fused salts that are not understood.

So far only processes in which direct currents are used and the products are obtained by electrolysis have been considered. By far the greater part of electric furnace products are made solely by heat produced by the current. It is in this branch of applied electrochemistry, called electrothermics, that the greatest developments have occurred in the past years.

Before discussing the different products it would be well to mention one or two advances in electric furnaces themselves. The first is a new kind of carbon electrode known as the Söderberg self-baking continuous electrode, perfected in Norway in 1918, and recently installed at Anniston, Alabama.[32]

It is made by feeding continuously unbaked electrode mixture to the furnace and the mass is baked by the heat of the furnace in which it is used. The operation is continuous during the life of the furnace, and the difficulty involved in changing electrodes over a hot furnace is avoided. It is also a more economical electrode. Electrical contact is made as near the roof of the furnace as convenient, when the carbon has become conducting, and encircles an iron casing in which the electrode mixture is held. The casing adds to the conductivity of the electrode, holds the shape and size while new mixture is added, and protects the carbon from oxidation before entering the furnace.

The raw electrode mixture is the same as in ordinary carbon electrodes which are to be baked, consisting of coke, semi-graphitized anthracite, tar, and pitch, finely ground and mixed together at about 80° C. This is stamped into the iron casing. The casing is made in sections, which are riveted or welded to old ones to extend the electrode. The casing is fed into the furnace along with the electrode, and is of course melted off in the furnace. The current density in one of these electrodes is 4.2 amperes per square centimetre in a 34-inch electrode.

This process requires a platform above the furnace.

An entirely new type of electric furnace has recently been developed by Professor Northrup in which the heating is produced

[32] Richards, *Tr. Am. Electroch. Soc.*, **37**, 169 (1920); **38**, 351 (1920).

by the eddy currents induced in the material to be melted by a high frequency current.[33]

Coming now to electrothermic products, ferro-alloys are important because of the enormous increase in production between

FIG. 8.
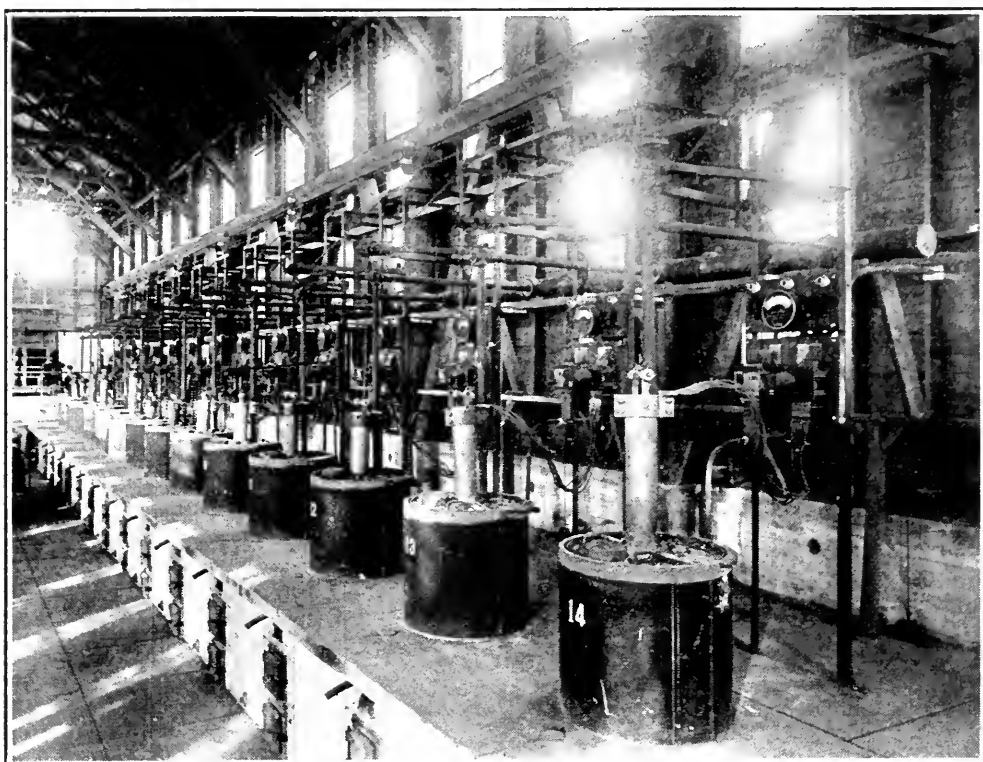
United Lead Company, Frary Metal Plant, Keokuk, Iowa.   Cowen, Simpkins & Hiers.
Battery of electrolytic pots.   Courtesy American Electrochemical Society.

1910 and 1918. In 1910 there were two ferro-alloy plants in the United States and Canada, using 20,000 KVA.

In January, 1920, there were 40 plants using 200,000 KVA, so that at the time of the Armistice the United States led the world in ferro-alloy production.[34]   Since then, however, 75 per cent. of these plants have shut down. The two most important developments among the ferro-alloys have been the electric smelting of manganese ores and the increased use of molybdenum in steel.

The electric furnace refining of steel is a comparatively new

[33] *Tr. Am. Electroch. Soc.* for 1921.
[34] Keeney, *El. J.,* **17,** 206 (1920).

industry, as it was just beginning 13 years ago, and at the beginning of 1920 there were 1000 furnaces for melting and refining steel built or under construction throughout the world. About one-third this number are Héroult furnaces.[35]

The most recent improvements in the construction of electric steel furnaces have been directed toward shaping the interior so as to lengthen life of the lining. There is such a narrow margin of temperature between the liquid steel and the melting point of the lining that overheating and the action of the slag are very apt to attack the lining rapidly. This difficulty is aggravated if the electrodes are so placed that the lining is heated more at one place than another. In the three-phase Héroult steel furnace the three electrodes are placed in the form of a triangle. In more recent designs of three-phase furnaces such as the Vom Baur and the Ludlam furnaces, the electrodes are placed in a straight line and the contour of the lining made such that at the slag line the temperature is approximately the same throughout.

The electric smelting of iron ore, originally suggested by Sir William Siemens in 1878, has within late years been carried out industrially in Norway, Sweden, Switzerland, Italy and Japan. It was also attempted in this country, but was given up in 1914. Electrolytic pig iron is made only where coke is scarce and water power plentiful.

In France[36] there was a great development during the war of an electric furnace process for converting steel turnings from munition plants into a low carbon cast iron, high in silicon and low in sulfur and phosphorus for the production of cast iron shells. This is called synthetic electric furnace cast iron. While previously low carbon steel has been carburized to high carbon steel, cast iron had never been made in this way. This has also been done in this country.[37]

The electric smelting of zinc has been carried out in Sweden since 1901. Although this has been extensively investigated in this country in recent years, and the chief difficulty, the production of blue powder, has been solved,[38] still no zinc is smelted

[35] See Rodenhauser, Shoenawa, and Vom Baur, "El. Furnaces in the Iron and Steel Industry."

[36] Keller, *Tr. Am. Electroch. Soc.*, **37**, 189 (1920).

[37] *Chem. Met. Eng.*, **26**, 312 (1922).

[38] Keeney, *Elec. J.*, **17**, 206 (1920).

commercially here or in Canada. Whether this method will ever compete in this country with the electrolytic extraction already described remains to be seen. The zinc experts differ in their predictions. It is interesting to note that zinc is the only metal for which serious attempts have been made to employ all three electric

Fig. 9.
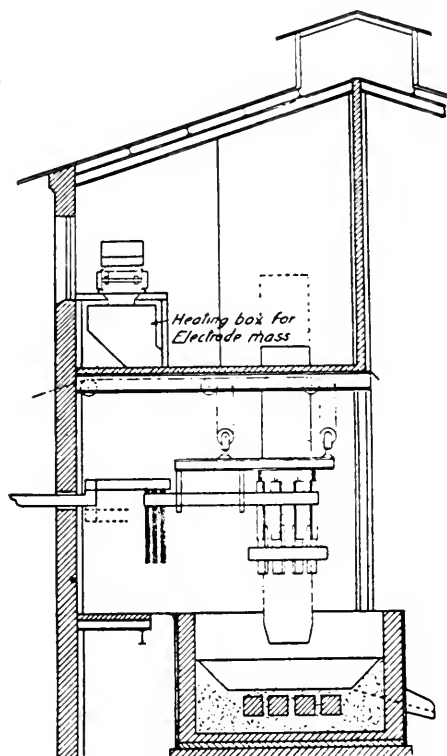
Söderberg self-baking continuous electrode.

methods of production—smelting, electrolysis of a fused salt, and wet electrometallurgy.

The use of the electric furnace has in recent years been extended to the brass industry, for melting brass in foundries. By the use of large melting units, with closed melting chambers free from oxygen and products of combustion, electric melting is said to have revolutionized metal handling methods and produces a more uniformly high quality of product, with less labor and less metal loss, than have previously been possible to attain.[39]

The most important of all the electrochemical industries will

---

[39] St. John, *Tr. Am. Electroch. Soc.* for 1921.

probably eventually be the fixation of atmospheric nitrogen. While in recent years no new process of importance has been invented, an immense amount of research has been carried out to perfect methods already known, especially the fixation by the synthesis of ammonia, called the Haber process. Ammonia is formed when nitrogen and hydrogen are heated electrically to about six hundred degrees in contact with a suitable catalyzer. The history of the development of this process is very interesting. One of the first researches for the purpose of testing this reaction as a means of fixing nitrogen was carried out by Haber and Van Oordt [40] in 1905, with very discouraging results. It was found that at atmospheric pressure, if the temperature were high enough to make the velocity of the reaction have an appreciable value, the equilibrium conditions were very unfavorable, while at lower temperatures where the equilibrium is favorable, the velocity of the reaction was too slow. Still, in spite of the unpromising characteristics of this reaction it was developed during the war in Germany to large scale production.[41] This was done by finding a good catalyzer which allows a lower temperature to be used, and by compressing the gas mixture of nitrogen and hydrogen to something like 200 atmospheres, which improves the yield because there is a volume contraction when ammonia is formed. The ammonia can be oxidized with a high efficiency to nitric acid, by the Ostwald process of mixing with oxygen and passing through a hot platinum wire gauze. The ammonia is first oxidized to nitric oxide which is then passed into water with the production of nitric acid.

During the war a plant was built and operated by the United States Government for large scale synthetic production of ammonia, using a catalyst invented by de Jahn.

A more recent development is the Claude process [42] in which everything is essentially like the Haber process except that the gases are made to react under a pressure of 1000 in place of 200 atmospheres. This increases the efficiency from 13 per cent. by the Haber process to 40 per cent. This process is now in successful operation in France.

Of all methods of fixing atmospheric nitrogen, the absorption by calcium carbide to form calcium cyanamide when heated in an

[40] Z. anorg. Ch., **44**, 341 (1905).
[41] See description of plant at Oppau, Chem. Met. Eng., **24**, 305 (1921).
[42] Chem. Met. Eng., **23**, 22 and 395 (1920).

electric resistance furnace to about 1000° C. is by far the most extensively used. The product is used as a fertilizer or to make ammonia by treating with superheated steam. A further use of calcium cyanamide recently has been developed successfully in this country, while abroad it was more or less of a failure.[43] This consists in changing cyanamide to cyanide by fusing in an electric furnace with sodium chloride. The product is used in the cyanide process for extracting gold and silver from ores.

There is a method of fixing atmospheric nitrogen which produces sodium cyanide directly, known as the Bucher process, consisting in heating sodium carbonate, carbon, and nitrogen in the presence of iron as a catalyzer. This reaction was discovered in 1846, and many unsuccessful attempts were made to use it on a commercial scale. In recent years Professor Bucher [44] has revived interest in it by his extensive researches. During the war a government plant was put up at Saltville, Virginia, to manufacture cyanide by this process, but the heating was done by gas. It is probable, however, that eventually electric furnaces will be used here also,[45] especially as rather careful temperature control is necessary. There is, it seems, no plant making cyanide by this method at present.

Clarification of Sugar Solutions.—In the determination of reducing sugars, their solutions are frequently clarified by treatment with basic lead acetate and removal of the resulting precipitate by filtration. Any excess of lead is then removed by precipitation with a suitable reagent; the solution is filtered and used for the analytical determination. DUANE T. ENGLIS and CHUK YEE TSANG, of the University of Illinois (*Jour. Am. Chem. Soc.,* 1922, xliv, 865–867), added basic lead acetate to solutions of dextrose and fructose, and used aliquot portions for removal of the lead by means of each of the following reagents: Potassium oxalate, potassium sulphate, potassium sodium tartrate (Rochelle salt), sodium carbonate, and disodium phosphate. They studied the adsorption of these sugars in the lead precipitate by determination of the reducing sugar content of the original solution and of the filtrate from the lead precipitate. Disodium phosphate was found to be the most satisfactory reagent for the removal of lead, since it gave rise to a minimum loss of sugar, and almost invariably yielded a clear filtrate.   J. S. H.

[43] Landis, *Tr. Am. Electroch. Soc.,* **37,** 653 (1920).
[44] *J. Ind. Eng. Chem.,* **9,** 233 (1917).
[45] *Chem. Met. Eng.,* **26,** 124 (1922).

CONTRIBUTIONS TO THE CHEMISTRY AND TECHNOLOGY OF GELATIN AND GLUE.*

BY

ROBERT HERMAN BOGUE, Ph.D.

Industrial Fellow of the Mellon Institute of Industrial Research of the University of
Pittsburgh, and Research Chemist for Armour and Company of Chicago.

I. INTRODUCTION.

Historical Considerations.—We are unable to penetrate the archives of the early human race to a date where we may say with assurance that glue was not yet discovered. Certain it is that this material was in use as an adhesive in the days of the great Pharaohs of Egypt. Among the stone carvings of the ancient city of Thebes of the period of Thothmes III, the Pharaoh of the Exodus, and at least 3300 years old, is one depicting the gluing of a thin piece of a rare wood of red color to a yellow plank of sycamore. The carving (Fig. 1) shows a pot of the glue being heated over a fire, and several samples of veneered and inlaid wood. One of the figures is spreading the glue with a brush, and in the lower section the workmen are preparing the thin slabs of veneer.

In the Roman Period mention is made to the value of glue by Lucretius, Pliny, Varro, and Cicero, and in the middle ages Shakespeare and Francis Bacon referred to it.

The earliest record of manufacture that can be traced directly from the present day dates back to the time of William III of Holland, where it was manufactured in 1690. In 1754 appears the first mention of glue in patent literature (British Patent 691, May 23, 1754). This refers to the preparation of "a kind of glue called fish glue," made from "the tails and fins of whales, and from such sediment, trash, and undissolved pieces of the fish as are usually thrown away as useless" after extraction of the oil.

The older glues had been made from "the hides of bulls," according to Lucretius and Pliny, and bones were apparently not utilized for the purpose until about 1814, at which time a patent was granted for the treatment of bones with acids, and the con-

---

version of the residue into glue. Steam under pressure " conveyed into a mass of bones in such a manner as to extract therefrom a gelatin adapted for the purpose of glue " was first described in 1822. Sulfurous acid was introduced in 1838, and vacuo evaporation in 1844.

FIG. 1
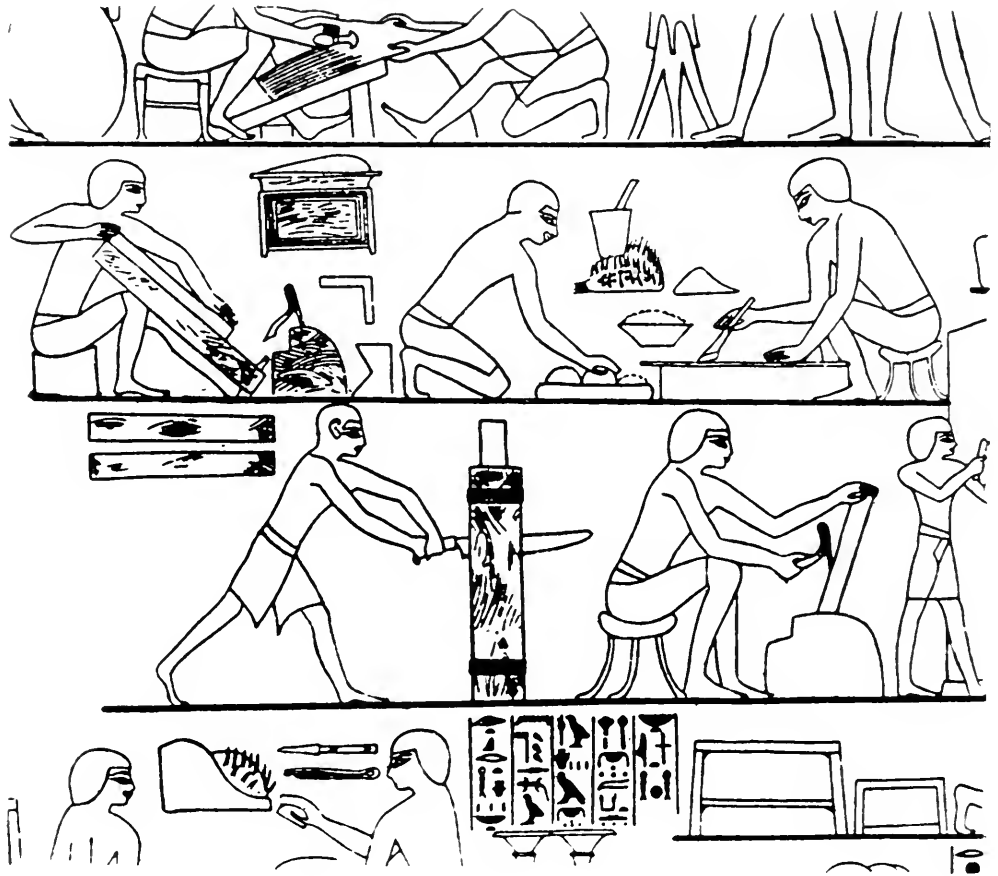
Veneering and the use of glue in Ancient Egypt.

The first mention of the manufacture of a gelatin for edible purposes is found in a patent by Arney in 1846. He prepared a powdered gelatin " for forming compositions from which may be prepared jellies and blanc-manges; also, when mixed with farina or starch or starchy vegetable flour, for thickening soups, gravies, etc."

The application of " currents of air artificially dried, either by heat or any of the drying compounds in common use, such as concentrated sulfuric acid or fused chlorid of calcium," was intro-

duced in 1847. A few other important mechanical devices for
speeding up the cooling of the product, for pulverizing, and for
making a nearly anhydrous powdered glue have been added to
the installment of the larger factories in recent years, but the
operations to-day are otherwise not greatly different from those
which were in practice a hundred years ago.

The earliest official record of the United States Government
wherein glue is mentioned seems to have been in a compendium of

TABLE I.

Domestic Production, Imports, and Exports of Gelatin and Glue, 1914 and 1919.

1914.

Material	Domestic Production	Total Imports	Total Exports
Gelatin, manufactured		$875,588	$13,595
Glue	$19,725,703	1,725,703	266,334
Mucilage		....	26,182
Isinglass and Fish Glue		70,212	......
Total	$19,725,703	$2,755,893	$306,111
Hide Cuttings and other glue stock	no data	$1,510,608	....

1919.

Material	Domestic Production	Total Imports	Total Exports
Gelatin, manufactured	no data	$241,835	$1,489,625
Glue and size		208,882	
Total		$450,717	$1,489,625
Hide Cuttings and other glue stock		$978,514	....

all the manufactures of the several counties of each state which
was compiled for the year 1810. In this there are listed six estab-
lishments making glue in Pennsylvania, with a total product value
for the year of $53,206, and one in Maryland with a product value
of $500. In no other state is glue mentioned as being produced.

Comparative Statistics.—The manufacture of glue and gelatin
in this country since 1810, and the most recent data available
upon imports and exports, are given in the tables, taken

mainly from the Census Reports of the Department of Commerce and the Bulletins of the Bureau of Foreign and Domestic Commerce (especially *Bull.*, **82**, 1919).

FIG. 2.
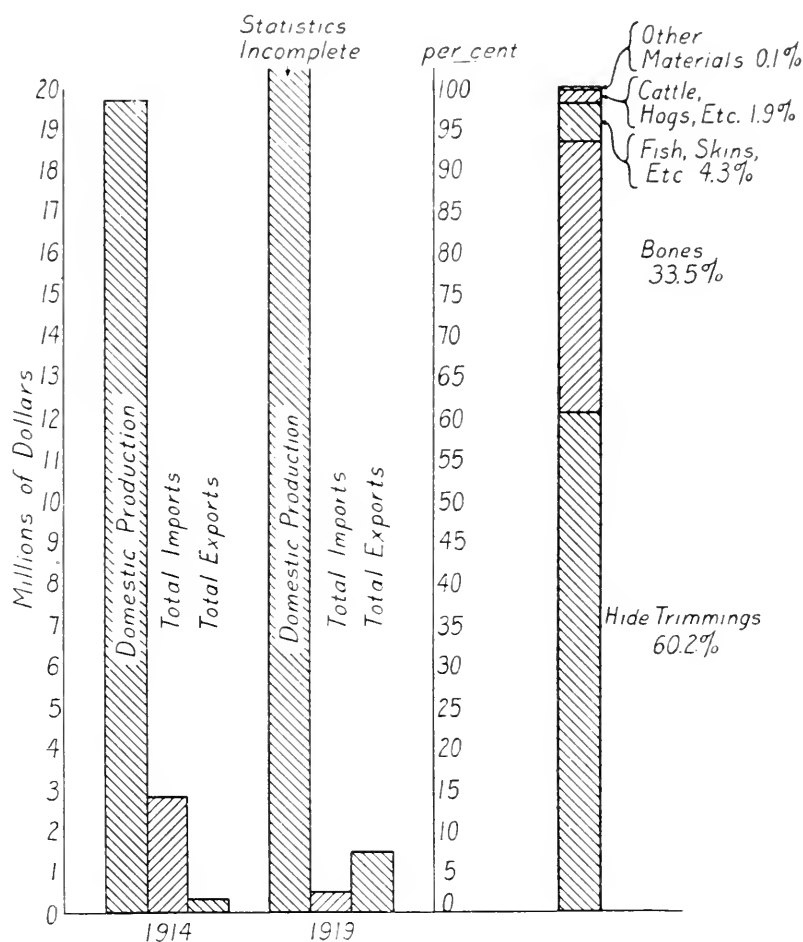
The domestic production, total imports, and total exports of glue and gelatin for the years 1914 and 1919.

Distribution of glue manufactured from various materials in the United States in 1900.

In Table I and Fig. 2 is shown a comparison of the domestic production, the total imports, and the total exports of glue and gelatin for the years 1914 and 1919. The most striking feature observed here is the enormous increase in exports (about 380 per cent.) and decrease in imports (about 510 per cent.) which occurred in that five-year period.

Table II and Fig. 3 show the number of establishments employed in manufacturing glue or gelatin as their principal product,

the capital invested, and the value of the product, for the census
years from 1810 to 1914, and the distribution of manufacture
among the several states in the latter year. It is observed that the
capital invested and the value of the product have quite steadily
increased, whereas the number of establishments has decreased

TABLE II.

*Glue and Gelatin Manufactured in the United States from 1810 to 1914.**

	Number of Establishments	Capital	Value of Product
1914	57	$17,162,000	$13,733,000
1909	65	14,289,000	13,718,000
1904	58	10,673,000	10,035,000
1899	61	6,144,000	5,389,000
1889	62	4,859,000	4,270,000
1879	82	3,917,000	4,324,000
1869	70	1,955,000	1,710,000
1859	62	1,053,000	1,186,000
1849	47	520,000	652,000
1810	7	....	53,706

Distribution by States for 1914.

Illinois	9	$5,552,170	$3,731,375
Massachusetts	11	2,956,497	2,588,733
Pennsylvania	8	2,820,250	2,028,767
New York	9	2,459,102	2,483,254
Indiana	3	356,295	280,251
All others †	17	3,018,048	2,620,449

*From establishments engaged primarily in the manufacture of glue or gelatin.
†Includes: Ohio, 5 establishments; California, 3; Wisconsin, 2; and 1 each in Connecticut,
District of Columbia, Iowa, Kentucky, Main, Maryland, and New Hampshire.

since 1879 from 82 to 57. This means that the industry has
become more centralized and that a number of small factories
have given place to larger ones. Illinois leads in 1914 in the
capital invested and the value of the product, although Massa-
chusetts has a greater number of glue and gelatin establishments.

It is sometimes overlooked that glue and gelatin are also pro-
duced in large amounts by establishments that are devoted
primarily to the manufacture of some other product. The
slaughtering and meat-packing establishments especially produce

large amounts of glue and gelatin, but these are not included in Table II.

Tables III and IV are compiled to give data upon the relative amounts of glue manufactured in glue and in other establishments

FIG. 3.
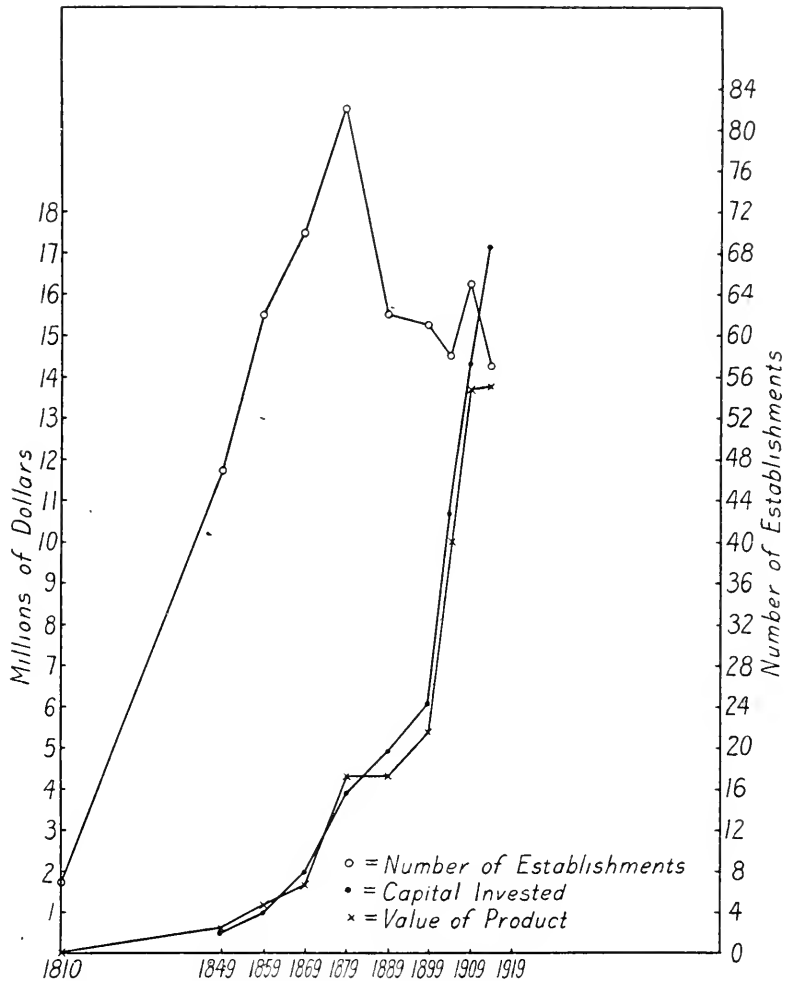
The glue and gelatin manufactured in the United States from 1810 to 1919.

in 1900 and in 1914, and the relative amount of glue made from the several chief sources, as hides, bones, etc. (See Fig. 2.) In 1900 there was very nearly as much glue made in slaughtering as in glue establishments, but in 1914 only 15.7 per cent. of the value of the total output came from slaughter houses. Five and seven-tenths per cent. came from fertilizer establishments, and 9.0 per cent. from all others, as plants manufacturing sand and emery

paper, tallow, soap stock, food preparations, oleo oil, and fish oil. More than 60 per cent. of all glue (in 1900) was made from hide pieces, fleshings, sinues, leather cuttings, etc., and 33.5 per cent. from bones. Fish skins and refuse contributed 4.3 per cent.

TABLE III.

Distribution of Glue Manufactured in Glue Establishments and in Slaughtering Establishments in 1900.

	Total Pounds	Made from hide trimmings, etc.	Made from bones	Made from cattle, hogs, etc.	Made from fish skins and waste	Made from other materials
Glue Establishments	34,984,448	29,036,901	3,109,165	66,666	2,731,156	40,560
Slaughtering Establishments	34,516,761	12,780,832	20,183,562	1,282,367	270,000	......
United States	69,501,209	41,817,733	23,292,727	1,399,033	3,001,156	40,560
Percentage Distribution, United States	100.0	60.2	33.5	1.9	4.3	0.1

TABLE IV.

Value of Glue Manufactured in Glue and Other Establishments in 1914.

	Quantity pounds	Value	Percentage by value from the different establishments
Glue Establishments	40,844,650	$13,732,824	69.6
Slaughtering Establishments.		3,088,764	15.7
Fertilizer Establishments ...		1,131,243	5.7
All others (including sand and emery paper, tallow, soap stock, food preparations, oleo oil, and fish oil)	no data		
		1,772,872	9.0
United States		19,725,703	100.0

II. TECHNOLOGICAL ASPECTS.

Manufacturing Operations.—As indicated in the last section, there have been few fundamental improvements in manufacturing operations in recent years. The technic of the operations, the substitution of machinery for hand labor, the selective treatment of different types of stock, and the improvements in control have advanced markedly, however, and much research has been directed towards these ends. It has been one of the aims of the industrial

fellowships at the Mellon Institute to perfect these processes and no effort has been spared in bringing the many steps in the manufacture to a rigidly scientific basis. A given amount of a given stock should produce a definite predetermined quantity of product

Fig. 4.
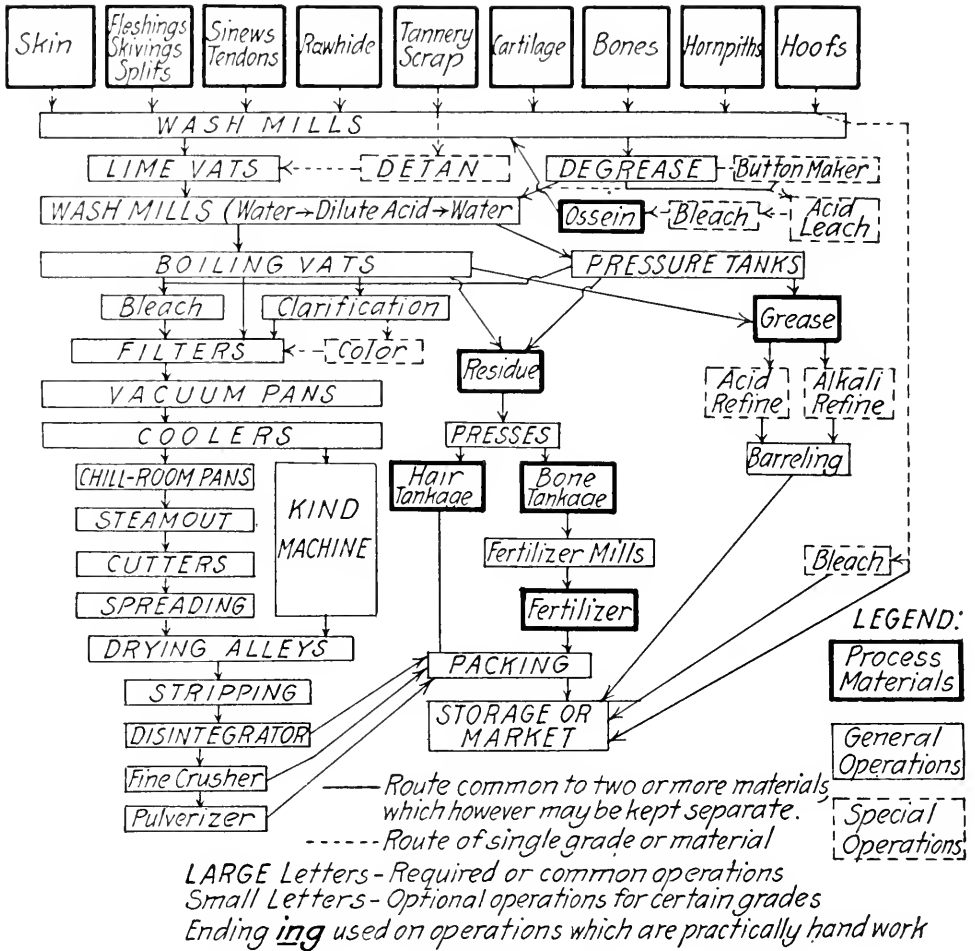
The operations in the manufacture of glue (by R. C. Shuey).

of a particular grade, and any failure to do so must be regarded as an indication of inefficiency at some stage in the operations. A graphic illustration of the several steps in the manufacture is shown in Fig. 4.

It has been shown that different types of stock will produce different qualities of product, and this has necessitated a careful separation of the various animal parts which find their way to the glue or gelatin manufacturer. If a product of specified properties

is desired, a particular type of stock, treated in a specified way, must be employed. Hide pieces, fleshings, and sinews each give their own type of product, and the hides of oxen, calves, sheep and other animals are kept separate for the same reason. Dense bones react differently from porous bones, and the ossein obtained by dissolving the mineral matter of bones prior to making into glue or gelatin produces a much higher grade of material than the untreated bones. These facts are all taken advantage of in manufacture.

Even the thoroughness of washing stock is a matter of no little concern, for it has been demonstrated that the presence of blood or other albuminous substances imparts to the product properties which are not desired. (*Cf.* section IV.)

It has been common practice for a great many years to allow all hide, fleshing, sinew, and ossein stock to stand in vats of a suspension of lime in water for from four to twelve weeks, with two or three changes, before cooking the material. This operation has been known to plump or swell the stock to many times its original volume, and upon heating with water a much more rapid solution took place. It has also been shown that the lime treatment dissolves mucinous and albuminous substances which may be present, and leaves the collagen which, on hydrolysis, is converted into gelatin.

Some attempt has been made to substitute other material for lime, and not without some degree of success. Acids have been found to produce a swelling in a shorter period of time, but the foreign proteins are not dissolved by acids. Other alkalies and alkaline substances have also been used, and while a proper control results in good yields, the greater cost makes them of questionable value for replacing lime. From a study of recent work on swelling (*Cf.* section IV) it is apparent that the optimum results are obtainable at certain concentrations of H-ion, and as long as such concentrations are attained *and maintained* it is a matter of more or less indifference what acids or bases are used. A saturated solution of calcium hydroxid possesses about the most favorable OH-ion concentration, and has the additional attribute of being only slightly soluble, so that as the OH-ion is absorbed by the stock more will as steadily be supplied by the solution of undissolved lime, so that a constant alkalinity is maintained. This

is of the greatest importance, as the control is rendered entirely automatic.

The excess of lime is removed as far as practicable by washing, and usually some acid is added to assist in the process. Sulfurous acid is especially valuable for this purpose as it serves also as a bleach and a disinfectant. Phosphoric acid is not well adapted as it has been found to favor the production of an insoluble gelatin phosphate. Cloudy and flocculent precipitations have been many times traced to this cause.

It is generally agreed that the " boiling " operation should be conducted in a slightly acid solution, but conclusive tests have not yet been made to settle this point. Experiments are at present being conducted at the Mellon Institute from which it is hoped to solve this question. The most favorable conditions of temperature and duration of heating are also being investigated.

The dissolved glue or gelatin may be filtered, if desired, through loosely packed paper pulp, or it may be clarified by the addition of a little albumin to the cool solution, and the latter then warmed till the albumin coagulates. Upon settling, the albumin carries down suspended material, leaving a very clear sparkling product.

After concentration in vacuo the liquid may be dried in any of several ways. The older method was to allow pans of the liquid to gel in a cold room, cut into sheets with wires, place on nets, and dry in an alley through which warm air was circulating. A great improvement over this method was the introduction of the Kind-Landesmann machine consisting of an endless belt a yard wide upon which the glue was poured in a thin layer. The belt travelled slowly through a cold chamber, causing the glue to gel, and the gel was then transferred mechanically to the nets, and dried in the alleys as before. Some glues are dried by revolving slowly in the liquid a large steel drum heated with steam on the inside. The glue adheres to the drum in a thin layer, and in the course of one revolution is dried and scraped off. Spray drying is a method that offers many inducements, but up to the present has not been largely used. The liquid is simply injected as a spray into a warm low pressure compartment. The water evaporates almost instantaneously, leaving minute hollow spheres of dry product. This is practically cold-water soluble.

The most favorable conditions for drying of the jelly in the

alleys have been studied in detail at the Mellon Institute. Methods for a rigid control of humidity and temperature have been developed, and psychrometric curves prepared by R. C. Shuey (Fig. 5) may be used to much advantage in determining the most favorable temperature for a given humidity, and the maximum efficiency, of any given set of drying conditions.

FIG. 5.
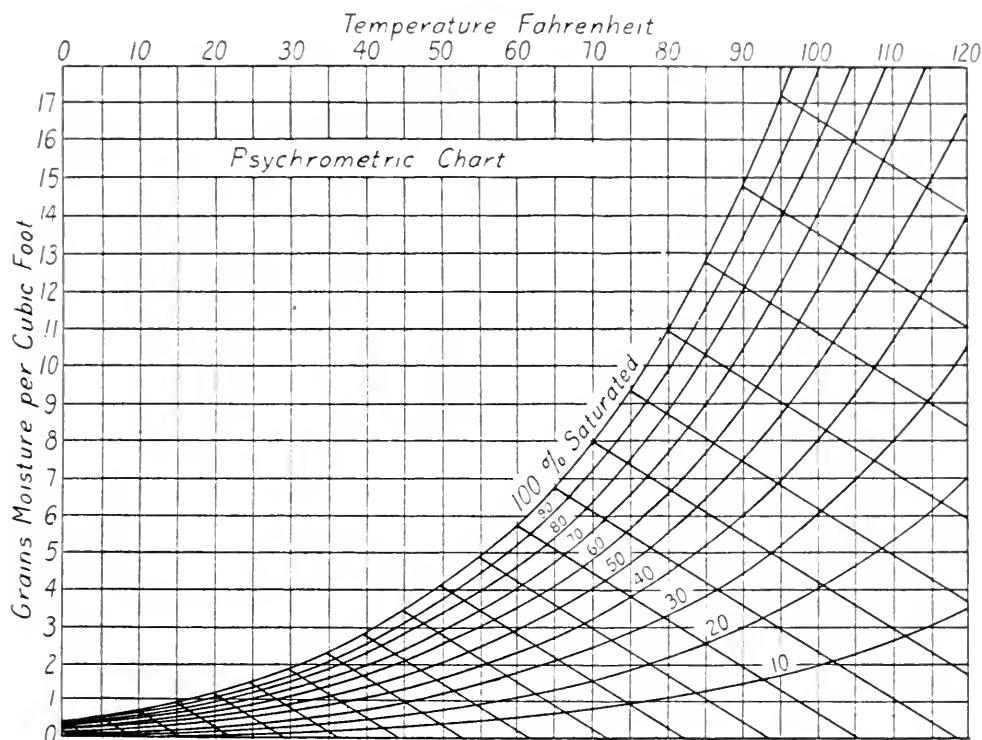
These are but a few of the most important advances that have been made in the technical operation of the glue and gelatin plant.[1]

Evaluation.—The chaotic condition of grade specification in gelatins and glues has been a source of the greatest annoyance to artisans and chemists alike, and the writer has given much time to the establishment of standard tests [2] which will not only differentiate the products consistently, but which will be based upon some fundamental property, will be easily and rapidly made, and

[1] For a more complete description of modern manufacturing operations the reader is referred to the author's treatise, "The Chemistry and Technology of Gelatin and Glue," to be published by the McGraw Hill Book Co. of New York, 1922.

[2] R. H. Bogue: *J. Ind. Eng. Chem.,* **14** (1922), 435.

will be capable of expression in simple and readily under-
stood terms.

A great many methods have been described for the testing of
glues and gelatins. These include numerous procedures for meas-
uring viscosity, jelly strength, melting point, and gelatin content.
In each case it was assumed that the method was correct in prin-
ciple, and all that was required was the perfection of the technic.
Except in a few instances there was no legitimate basis for
the assumption.

In this country the usual criterion for grade is based on either
the jelly strength at 10° to 15° C. or the viscosity at 60° or
80° C. But the writer has shown [3] that neither of these tests is
in all cases indicative of either the gelatin content or the adhesive
strength, and it would seem that gelatin content or adhesive
strength should be regarded as the basis of gelatin or glue value.
It was found, however, that gelatin content, adhesive strength,
and melting point were all perfectly parallel functions. Any meas-
ure of one of these properties would therefore indicate correctly
the other two, or, more especially, the order of the other two in a
series. Neither gelatin content nor adhesive strength is easily
determined and would be impracticable for routine tests.

The melting point test was studied by many methods, and it
was observed that the measurement of this property by plotting
a viscosity-temperature curve, using a capillary pipette as a viscosi-
meter, and extrapolating to the temperature at which the rate of
flow would be zero, corresponded well with other methods. It then
became apparent that the extrapolation below 32°–35° C. was
unnecessary, and that a viscosity measurement at that temperature
resulted in an exactly similar differentiation.

A simple and accurate method for grading was thus obtained.
The final perfection of technic involved the use of the MacMichael
viscosimeter, the viscosity in centipoises of an 18 per cent.
solution (dry basis), at 35° C. being noted. The conversion
of MacMichael degrees to centipoises is easily done, after a pre-
liminary calibration against a liquid of known absolute viscosity,
as castor oil, by a mere glance at a conversion curve. This being
a straight line makes errors of observation improbable, and a
setting of the instrument may be made at which the readings
indicate directly in absolute units.

---

[3] R. H. Bogue: *Chem. Met. Eng.*, **23** (1920), 61, 105, 197.

We have, then, instead of the multitudinous array of devices for determining grade, a standard instrument; the measurements are rapidly and accurately made; the results express actual value in reference to either gelatin content or adhesive strength; and the data are expressed in absolute units which are easily understood. For convenience the grade may be written as centipoises, divided by ten, placed after a letter referring to the type of stock used. Thus, H_{12}, B_5, G_{15} would signify respectively, a hide glue of viscosity between 120 and 129 centipoises; a bone glue of 50 to 59 centipoises; and a gelatin of 150 to 159 centipoises.

The H-ion concentration has been shown (*Cf.* section IV) to be of much value in specifying the properties of gelatin, and is therefore introduced as a regular test, to be made by either electrometric or calorimetric means on a 1 per cent. solution.

Other tests may be made to determine the adaptability of any given product to a particular service. These tests, as for grease, foam, jelly consistency, clarity, etc., should be made only when necessary to fulfil specifications, and should be carried out by standard procedures.

III. ECONOMICAL ASPECTS.

Glue Room Economy.—The extent of the waste [4] in glue due to unintelligent handling in the glue rooms of the consumers is difficult to estimate, but it is of very great proportions. It seems indeed incredible that workmen who have handled glue for a score or more of years should be so uninformed of the fundamental properties of the material. A few of these points will make the meaning clear.

A 12-quart pail will hold from 6 to 15 pounds of dry glue, depending on the thickness and size of the flakes. If ground, it will hold from 12 to 21 pounds. But very often glue batches are made up by volume instead of weight.

There is often no standard of viscosity for applying a glue. A workman will add water to satisfy his own judgment. And the temperature both of the wood and glue may be almost anywhere between 30° and 90° C. The viscosity variations with such changes in temperature are enormous.

The glue is often but partially soaked in cold water before heating, and some portions not soaked at all. An excessive tem-

---

[4] *Cf.* R. H. Bogue: *Chem. Met. Eng.*, **25** (1921). 443.

perature and prolonged heating is then necessary to bring the glue into solution.

The temperature used in bringing the swollen glue into solution is frequently so high that hydrolysis breaks the material down to proteoses and peptones. This hydrolysis injures severely the quality of the product. And the glue is usually allowed to remain at a high temperature for many hours at a time, and the injury is of course proportional to both the temperature and the time.

FIG. 6.
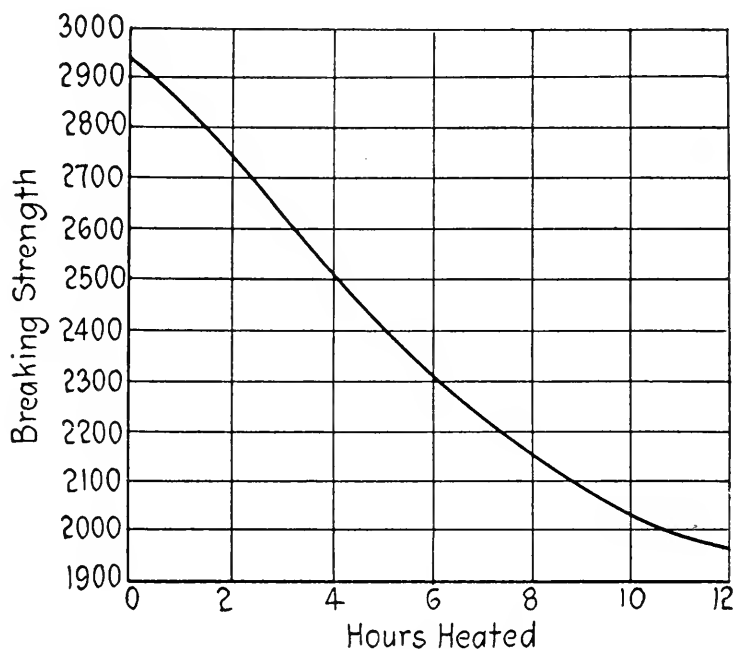
Effect of heating on breaking strength.

The matter of losses in glue due to overheating were of such great importance that a number of experiments were conducted to study the exact nature and extent of the losses.[5] It was found that at 80° C. a high-grade glue (H_{14}) was brought down to the equivalent of a low-grade glue (H_5) in twelve hours. In actual adhesive strength the loss was from 2900 to 1900 pounds per square inch, or about 85 pounds per square inch per hour. This is shown in Fig. 6.

That this is not exceptional is shown by reports of Linder and Frost,[6] who obtained a loss in strength of 30 to 45 per cent.

[5] R. H. Bogue: *Chem. Met. Eng.*, **23** (1920), 197. *Veneers*, **15**, No. 1 (1921), 30.

[6] Linder and Frost: *Eng. News*, **72** (1915), 178.

by heating a glue at 65.5° C. for 20 hours, and of the Forest Products Laboratory,[7] who obtained a loss in strength of approximately 50 per cent. by heating at 80° C. for 7 hours. The most favorable temperature was found by the latter to be at 60° C., for at lower temperatures bacterial decomposition becomes very rapid.

In spite of the unmistakable significance of these figures, however, the glues in many consuming plants are kept at high temperatures for long periods of time, enough being made up each morning to last through the day, and the residue of one day's run mixed into the batch for the following day. The reason why failures are still few under such conditions is that the consumer buys on a very high margin of safety, even 100 per cent. or more above the required strength. But such a procedure cannot be regarded as economic.

Even in the making of the joint there is possible a vast range of binding strength depending upon the pressure of joining. It was shown in the writer's laboratory[8] that an increase in strength from 800 to 1400 pounds per square inch in one case, and from 1900 to 2500 in another case, was obtained by increasing the joining pressure from 10 to 100 pounds per square inch. A further increase in the latter to 1000 pounds resulted in a further increase in strength to 1800 and to 3000 pounds per square inch, respectively. These data are illustrated in Fig. 7. The reason for this has been found to be only in the perfection of the contact between the two pieces of wood. The bond lies in the tensile strength of the fibrils of dry glue which run from the pores in one piece of wood to those in the other, and the complete elimination of the solid layer of glue *between* the two pieces seems desirable. This is accomplished by high pressure.

In some glue rooms the bacterial decomposition is at all times so far advanced that it is repelling to the senses to enter. Such conditions have even come to be regarded as a necessary part of glue handling. But it is absolutely indefensible and economically disastrous. In such places there is little or no effort made towards cleanliness. Glue pots are never washed or sterilized; the floor is not cleansed of its accumulating mass of spillings; fresh sweet glue is melted in pots containing putrid material; everywhere is

---

[7] U. S. Forest Service: *Technical Notes,* 104 (1920).

[8] R. H. Bogue: *Loc. cit.*

decomposition. Fresh milk will not keep sweet if put in sour bottles, and neither will glue.

But sour glue is not merely glue that does not smell good. It is rendered inferior by bacterial hydrolysis. A high grade of glue may be made almost valueless by a day of intensive degradation.

Applications in the Industrial Arts.—In carrying out one of the objects of the Institute, namely the dissemination of knowl-

FIG. 7.
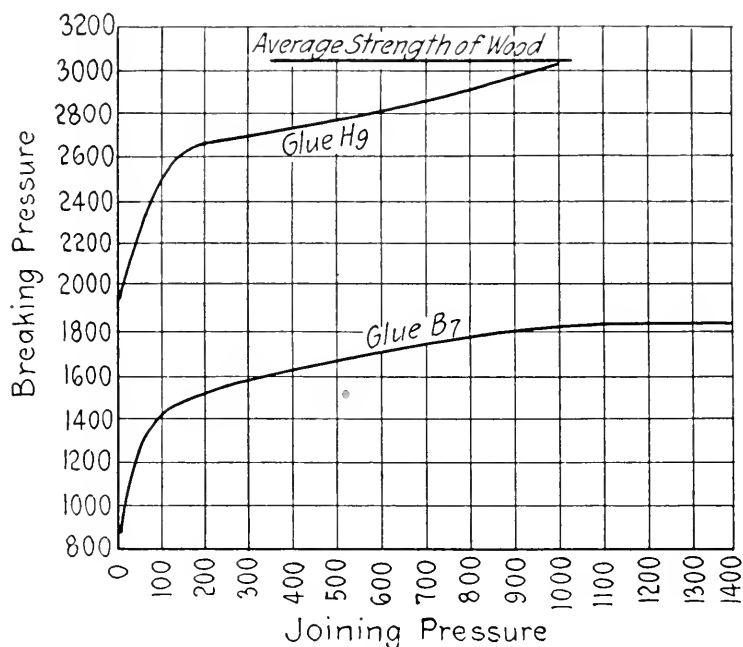
Effect of joining pressure on breaking strength.

edge, it has been found desirable, from time to time, to place special information directly before certain groups of people or trades that they may be informed of the progress of the science insofar as it is of direct interest to such groups. To this end a number of papers have been published in various industrial periodicals which have presented matter of interest to the several branches of manufacture represented thereby.[9]

---

[9] R. H. Bogue: "Glue Losses Due to Overheating," *Veneers,* **15,** No. 1 (1921), 30; "Gelatin in Ice Cream," *The Ice Cream Review,* **5,** No. 1 (1922), 20; "The Dietary Value of Gelatin," *The American Food Journal,* **17,** No. 2 (1922), 39; "Water Resistant Glues: Casein and Blood Albumin," *Chem. Age,* **30** (1922), 103; "Isinglass," *Chem. Age,* **30** (1922), 183; "Edible Gelatin," a series of seven papers in *The Candy Manufacturer,* **2** (1922), May to November; "Glue as an Adhesive," and "Glue Room Economy and Technology," *The Canadian Woodworker,* 1922, May to September.

While a detailed account of the many applications of glues and gelatins in the arts would be out of place in this paper, it will be of value as an aid to a proper understanding of the scope of our problem to point out that these products are used extensively in the following arts and processes:

As a binder for matches, sand and emery papers, abrasive wheels, rubber cements, artificial leather, moulding material, billiard balls, composition cork, imitation hard rubber, and calcimine. As a size for wall papers, writing papers, cotton, wool, and silk fabrics, straws, barrels, walls, etc. As a colloid gel for printing rollers, hectograph plates, artificial silks, artificial ivory, gelatin veneers as marble, travertine, malachite, mother-of-pearl, etc., and in making frosted glass. As a protective colloid for electrometallurgical processes, rubber, pickle baths, foamite, india ink, insecticides, photolithographic plates, and photographic emulsions. In addition gelatin finds service as a food, as a protective colloid and emulsifying agent in dietetics, as a binder and protective colloid in ice cream and jellies, in court plaster, capsules, and pharmaceutical preparations.

Gelatin as a Food.—The value of gelatin as a food is of such importance as to justify a few paragraphs at this place. For in the light of the statement so often heard that gelatin is not a complete protein, it is looked upon with indifference by dieticians, and on account of its unrefined relationship with glue, is too frequently regarded by the housewife as an impure product.

It requires, therefore, to be emphasized that although gelatin is not a complete protein, yet neither is albumin or fibrin or many other isolated proteins, but this does not detract from its desirability as one constituent of a balanced diet. Kirchmann [10] has reported that if gelatin is included in the diet to the extent of 12 per cent. of the required energy, the decomposition of body protein, or the requirement of other proteins necessary for equilibrium, is lessened by 27 per cent., and Krummacher [11] has found that 33 grams of gelatin will spare 14 grams of protein. Murlin [12] observed that protein nitrogen might be replaced by gelatin up to a half of the starvation requirement, while as much

---

[10] J. Kirchmann: *Z. Biol.*, **40** (1900), 54.

[11] O. Krummacher: *Ibid.*, **42** (1901), 242.

[12] J. Murlin: *Proc. Am. Physiol. Soc.*, **29** (1904).

as two-thirds may be replaced provided carbohydrates are present in such amounts as to provide a half to two-thirds of the total calorific requirement. Kauffman [13] has concluded that the failure of gelatin as a complete protein lies in the absence in its molecule of the three important amino acids, cystine, tyrosine, and tryptophane.

In addition to the value of gelatin as a producer of energy and a sparer of nitrogen, it unquestionably serves as a protective colloid and an emulsifying agent.[14] In natural milk, lactalbumin serves as the protective colloid preventing the coagulation of the casein, but woman's milk contains more than twice as much lactalbumin as cow's milk, while the latter contains nearly three times as much casein. In the infant's stomach the casein of cow's milk is rapidly coagulated by the acid of the gastric juice, but the addition of a little gelatin tends to retard this and to make the coagulum more finely dispersed. What is thus obvious in infant feeding is undoubtedly significant also in the normal dietary.

As an emulsifying agent gelatin tends to keep the fat in a finely divided condition. When casein is precipitated it carries down with it a considerable portion of fat, and troubles that have been experienced by the appearance of undigested fat have been relieved by the addition of gelatin.[15]

IV. PHYSICO-CHEMICAL RESEARCH.

Special Properties of the Colloid State.—Many studies have been reported in the past few years upon the viscosity, swelling, gelation, osmosis, etc., of protein systems. Wolfgang Ostwald has spoken of viscosity as a measure of the colloidality of a substance, and the mathematical conditions upon which the viscosity is dependent have been set forth by Einstein [16] and Hatschek.[17]

So long as the particles of dispersed phase occupy so small a proportion of the total volume of the system that they do not touch each other, the increase in viscosity is a linear function of the

---

[13] M. Kauffman: *Arch. Physiol. (Pflüger's)*, **109** (1903), 440.

[14] *Cf.* J. Alexander and J. Bullowa: *J. Am. Med. Assoc.,* **55** (1910), 1196; A. Jacobi, *Ibid.,* **51** (1908), 1216; J. Alexander, *Z. Chem. Ind. Kolloide,* **4** (1909), 86; **5** (1909), 101; **6** (1910), 197.

[15] Moore and Krombholz: *J. Physiol.,* **22** (1908), 54.

[16] A. Einstein: *Ann. Physik,* **19** (1906), 289.

[17] E. Hatschek: *Kolloid-Z.,* **7** (1910), 301; **8** (1911), 34.

concentration and independent of the size of the particles. The
equation is then written:

$$\eta' = \eta \,(1 - kf),$$

where η' is the viscosity of the system, η the viscosity of the con-
tinuous phase, f the ratio of the volume of the dispersed phase
to the total volume of the system, and k a constant which was
found by Einstein to be 1; by Hatschek to be 4.5; and by
Bancelin to be 2.9.

Just as soon, however, as the ratio of the volume of dispersed
phase to the total volume of the system becomes so great that the
particles touch each other, then the viscosity concentration curve
no longer remains linear, but becomes curvilinear. Under these
new conditions the viscosity is expressed, according to Hatschek,
by the equation:

$$\eta = \left(\sqrt[3]{A} \,\Big/\, \sqrt[3]{A} - 1 \right),$$

in which η is the viscosity of the system, and A the ratio of the
total volume of the system to the volume of the dispersed phase.
Since we cannot measure directly the dispersed phase volume
the value of A may be obtained by the rearrangement:

$$A = \left(\eta \,/\, (\eta - 1) \right)^{3},$$

and if the amount of dispersed substance is expressed in per-
centage, e.g., total volume divided by dispersed weight, then this
value, which Hatschek calls A', should bear a constant ratio
to A, or

$$A' \,/\, A = K.$$

This ratio has been rigidly tested in the writer's laboratory [18]
with the result that the value K was found not to be constant, but
to rise regularly to a maximum and thereafter to fall as regularly.

To explain this it was pointed out that the ratio A'/A is in
reality an expression representative of the volume occupied by
unit weight of dispersed phase. This apparent increase to a
maximum may be attributed to a failure of the formula to apply
at low concentrations, that is, the particles do not touch, but at
higher concentration there is little doubt from the evidence given

---

[18] R. H. Bogue: *J. Am. Chem. Soc.*, **43** (1921), 1764.

that an actual decrease in volume of particle takes place. This was explained by the writer as due to the resistance of the liquid medium to being drawn out into very thin films. As each particle of gelatin tends to take up water to attain its maximum volume, the liquid phase must be drawn into even thinner and thinner films, and such a process is opposed by the surface tension of the liquid. An equilibrium is therefore produced:

Surface tension (of d.m.) $\rightleftarrows$ *Solvation potential (of d.p.)*

The extent of this influence was found to be expressed by the equation:

$$\sqrt[n]{V^o_m} - \sqrt[n]{V_m} = s,$$

where V^o_m is the volume of dispersion medium when A'/A is at its maximum, V_m is the volume at any other concentration, and s is the decrease in volume per unit weight of dispersed phase at the concentration V_m. n was found to lie between 3 and 4 for gelatin sols.

The swelling, solution and gelation of gelatin have been studied by Martin Fischer and his collaborators.[19] They reported results upon the effects of the several phosphates, citrates, and carbonates of sodium on the above-mentioned properties, but failed to determine the hydrogen ion concentration of the solutions employed.

The effect of hydrogen ion concentration on the properties of gelatin has been emphasized by Loeb [20] and others, and the writer has contributed to this problem by studies not only with pure acids and bases,[21] but with alkali salts.[22]

A typical curve illustrative of the effect of a monobasic acid (hydrochloric) and a monoacid base (sodium hydroxid) on the swelling and viscosity of gelatin is shown in Fig. 8. The curves for gel strength are quite similar.

The behavior of several silicates of sodium which varied in their soda-silica ratio from 1 : 4 to 1 : 1 was especially studied. It was observed that the swelling and other properties of the gelatin increased as the proportion of Na_2O in the silicate molecule of the added solution increased, even though the actual weight of Na_2O

[19] Fischer and Hooker: *J. Am. Chem. Soc.*, **40** (1918), 272; Fischer and Coffman: *Ibid.*, **40** (1918), 303.

[20] Jacques Loeb: *J. Gen. Physiol.*, **1** (1918–19), 39, 237, 363, 483, 559.

[21] R. H. Bogue: *J. Am. Chem. Soc.*, on press.

[22] R. H. Bogue: *J. Ind. Eng. Chem.*, **14** (1922), 32.

added was the same in all cases. But this was adequately accounted for by the finding [23] that the hydrolysis of these silicates increased as the ratio $Na_2O : SiO_2$ increased. The OH-ion concentration accordingly increased in a similar manner, and the observed variation in swelling, viscosity, etc., of the gelatin was shown to be proportional to the *pH* of the solution.

The swelling and viscosity reach their maximum values at a *pH* of about 8.5 and 3.5, and decrease at higher or lower values. The jelly consistency, however, is high at *pH* values between 5.0 and 8.0 and between 4.5 and 3.5, but at 8.5 and at 3.0 it becomes lower, and is liquid above 9.0 and below 2.5. From this it is argued that gelation is largely dependent upon the tendency of the gelatin to become solvated, the volume occupied by unit weight of dispersed phase being the determining factor. When this volume is small or large the jelly consistency will be low, but at intermediate values of volume per unit weight, the jelly consistency will reach its maximum.

Osmotic pressure studies have been made by Loeb [24] and by Smith.[25] The outstanding feature of this latest work of Loeb lies in its ability to explain, by an application of the Donnan Equilibrium, the influence of H-ion concentration on osmosis and viscosity. Loeb postulates the existence in any protein solution of molecularly dispersed particles floating side by side with submicroscopic solid particles occluding water, the amount of which is controlled by the Donnan Equilibrium. The osmotic effects are determined by the molecular particles; the viscosity effects by the submicroscopic solid particles. Any influence in the solution (change in H-ion concentration) by which the molecular dispersion is increased at the expense of the solid particles will result in an increase in the osmotic pressure and a decrease in viscosity, and the opposite conditions would result in the reverse of these effects.

Of the most profound importance to an understanding of the behavior of the proteins are the brilliant experiments of Loeb by which he demonstrated their amphoteric character and defined in terms of H-ion concentration and valency the influence of added substances.[26]   He argued, supported by many experiments, that

[23] R. H. Bogue: *J. Am. Chem. Soc.,* **42** (1920), 2575.

[24] Jacques Loeb: *J. Gen. Physiol.,* **3** (1921), 827; **4** (1921), 73, 97.

[25] C. R. Smith: *J. Am. Chem. Soc.,* **43** (1921), 1350.

[26] Jacques Loeb: *J. Gen. Physiol.,* **1** (1918–19), 39, 237, 363, 483, 559.

the so-called Hoffmeister and Pauli series of ions no longer existed in an unexplainable sequence provided only that the concentration of H-ions and the valence were properly considered, and he showed conclusively that gelatin could exist in three forms. At *pH* of 4.7 gelatin was isoelectric, and in that condition was nearly union-

FIG. 8.
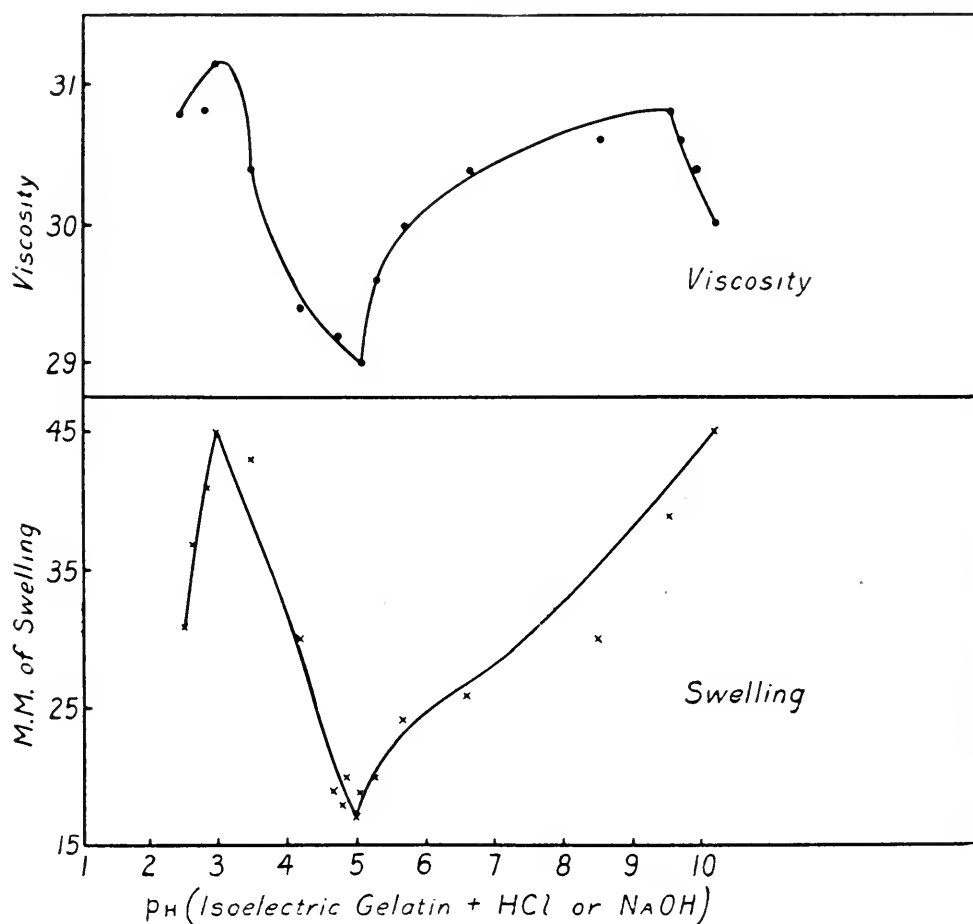
Influence of hydrogen ion concentration on the swelling and viscosity of gelatin.

ized, insoluble, and incapable of combining with the ions of inorganic salts. At *pH* less than 4.7 gelatin existed as cation, and in that condition could combine with the anions but not the cations of added salts. At *pH* greater than 4.7 gelatin existed as anion, and in that condition could combine with the cations but not the anions of added salts. All ions produced a depressing effect on the swelling, but monovalent ions had the least effect. H and OH ions increased the swelling only in that they resulted in an increased ionization of the gelatin.

Constitution.—There has been but a surprisingly small amount of work done upon the chemical composition and constitution of gelatin. Trotman and Hackford [27] developed a relationship between the " gelatinose " precipitated in a saturated solution of zinc sulfate, and the consistency of the jelly producible. This

FIG. 9.
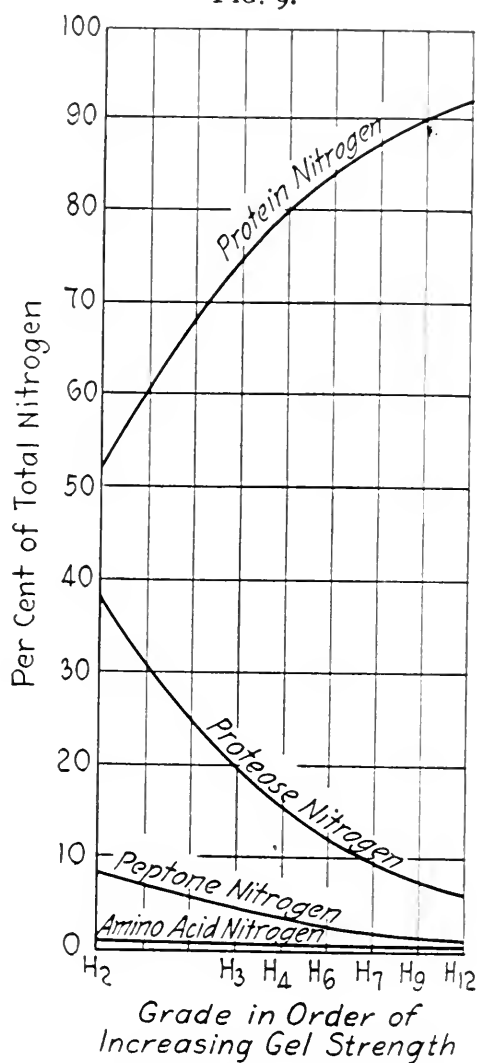
Variation in gel strength with composition. Hide glue.

method of examination has been extended by the writer to include a determination of protein, proteose, peptone, and amino acids.

A large number of glues and gelatins of all grades were examined for these constituents [28] by the following procedure. The protein and proteose were precipitated together at the isoelectric

[27] Trotman and Hackford: *J. Soc. Chem. Ind.*, **23** (1904). 1072.
[28] R. H. Bogue: *Chem. Met. Eng.*, **23** (1920), 105.

point with saturated magnesium sulfate solution. The protein was precipitated from another portion with a half-saturated solution of the salt. The nitrogen was determined in each and by difference the proteose nitrogen calculated. The amino acids were determined by Sörensen's formaldehyde titration method in the filtrate from the protein and proteose precipitation. The total nitrogen was determined, and the peptone calculated by difference. Results were expressed as percentage of total nitrogen.

FIG. 10.
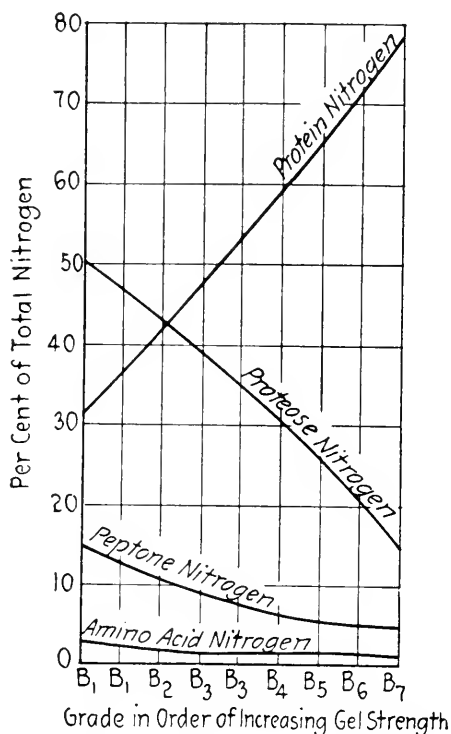
Variation in gel strength with composition. Bone glue.

The data show very well the relationship which the products of protein hydrolysis bear to the undegraded protein as the grade, expressed in viscosity at 32° C., changes. The curves for hide glues are shown in Fig. 9 and for bone glues in Fig. 10. The high-grade product is shown to have from 80 to 90 per cent. of its nitrogen in the form of protein, the balance being mainly proteose. The low grades may have as little as 30 to 50 per cent. of their nitrogen in the form of protein. A strong gelatin or glue is, therefore, one in which the nitrogen is mostly in the form of undegraded protein, and as this protein becomes hydrolyzed into proteose, peptone, etc., the strength of the product as regularly decreases.

The ultimate amino acid composition of gelatin has been reported by Emil Fischer [29] and others, but it was conspicuous that the amount of nitrogen accounted for by these esterification methods was only from 40 to 70 per cent. of the total. Recently, however, Dakin [30] has greatly perfected the older methods of separation originated by Fischer, and has succeeded in the remarkable recovery in pure form of 91.31 per cent. of the total nitrogen. Van Slyke and Hiller [31] have lately pointed out that there is a considerable amount of an unidentified base in the hydrolysis products of gelatin. The data of Dakin are shown in the following table:

TABLE V.

Amino-acid Content of Gelatin.

Glycine	25.5	Tyrosine	0.01
Alanine	8.7	Proline	9.5
Valine	0.0	Hydroxyproline	14.1
Leucine	7.1	Tryptophane	....
Serine	0.4	Histidine	0.9
Aspartic acid	3.4	Arginine	8.2
Glutamic acid	5.8	Lysine	5.9
Cystine	....	Ammonia	0.4
Phenylalanine	1.4		

The elementary analysis of gelatin was shown by Procter [32] to be:

C	50.06
H	6.79
O	24.79
N	18.36

from which he deduced the formula:

$$C_{35} H_{57} O_{13} N_{11}$$
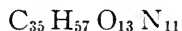
assuming that the molecular weight was 839. This value was obtained by a mathematical treatment of the equilibrium existing in a gelatin-acid system, assuming the gelatin to be a diacid base. By assuming the gelatin to be monoacid, Wilson [33] found a molecular weight of 768, and wrote the formula:

$$C_{32} H_{52} O_{12} N_{10}.$$
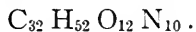
[29] Fischer, Levene and Anders: *Z. physiol. Chem.*, **35** (1902), 70.

[30] H. D. Dakin: *J. Biol. Chem.*, **44** (1920), 524.

[31] D. D. Van Slyke and A. Hiller: *Proc. Nat. Acad. Sci.*, **7** (1921), 185.

[32] H. R. Procter: *J. Chem. Soc.*, **105** (1914), 313.

[33] J. A. Wilson: *J. Am. Leather Chemists' Assoc.*, **12** (1917), 115.

The method of examining proteins suggested by Van Slyke [34] has been applied to gelatin by Van Slyke and to a large number of gelatins and glues by the writer.[35] Some relations of importance have been observed. In the first place there is a distinct variation observed on passing from the high to the low-grade product.

FIG. 11.
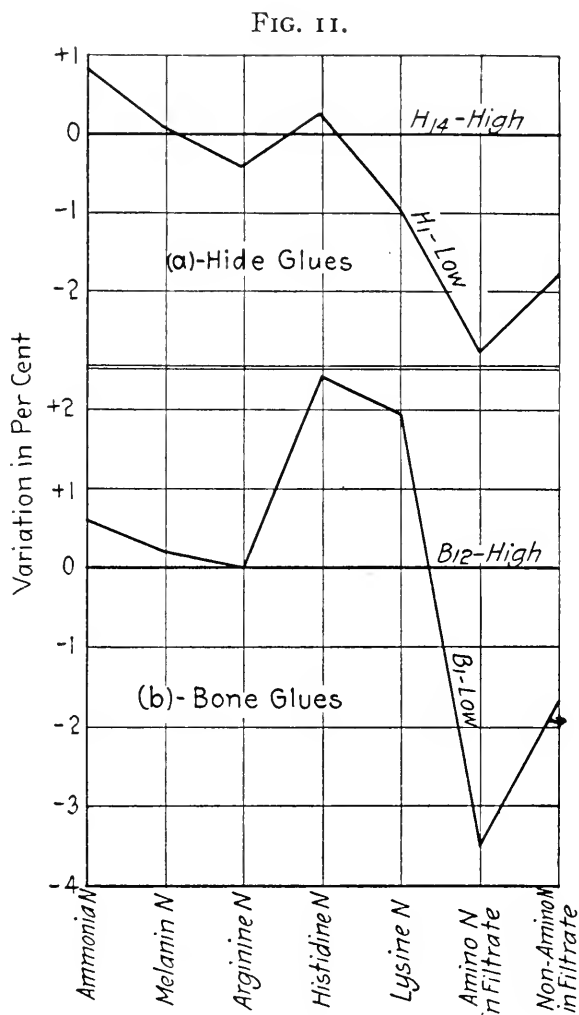
Variation in amino-acid constitution of high and low grade hide and bone glues.

This is seen in Fig. 11. And practically the same type of variation is observed on comparing the bone with the hide glues. The low grades, and the bone glues, have the higher ammonia, histidine and lysine content, and the lower arginine, amino, and non-amino nitrogen of the filtrate. The latter two groups contain practically all of the mono-amino acids.

---

[34] D. D. Van Slyke: *J. Biol. Chem.,* **10** (1911), 15; **22** (1915), 281.
[35] R. H. Bogue: *Chem. Met. Eng.,* **23** (1920), 154.

The explanation given to account for these differences is that as the cooking of the stock progresses, and higher temperatures and longer periods of heating are employed, more and more of the non-collagenous proteins become hydrolyzed. True collagen

FIG. 12.
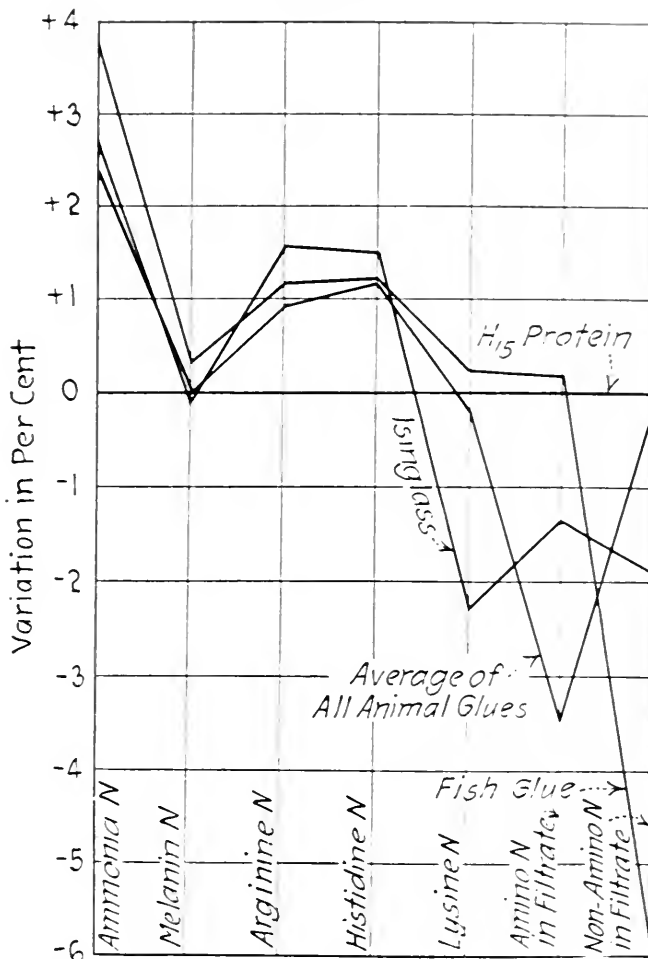
Variation in amino-acid constitution of different products.

is easily converted into gelatin, but more drastic treatment is required for the hydrolysis of the more resistent proteins. These include keratin, elastin, mucin, and chondrigin. The amino-acid composition of these is different from that of gelatin, and so becomes manifest upon the examination described above.

Fish glues and isinglass were also studied and were found to give higher arginine and histidine and lower proline and oxy-proline portions than any other types. This is shown in Fig. 12.

The following table shows some of the data:

TABLE VI.

Distribution of Nitrogen in Gelatins and Glues.

	Gelatin (Van Slyke)	Gelatin	Average Hide Glues	Average Bone Glues	Isinglass	Fish Glues
Ammonia N	2.25	1.33	2.90	4.55	3.98	5.15
Melanine N	0.7	0.78	0.59	0.91	0.68	1.12
Cystine N	0?	0	0	0	0	trace
Arginine N	14.70	12.61	13.90	13.17	14.20	13.80
Histidine N	4.48	0.82	2.19	1.78	2.33	2.04
Lysine N	6.32	8.34	7.97	8.28	6.06	8.58
Amino N of filtrate	56.3	60.00	56.89	26.27	28.65	60.20
Non-amino N of filtrate...	14.9	15.49	15.63	15.25	13.59	9.66
Total regained	99.02	99.37	100.02	100.21	99.49	100.55

Structure.—The structure of gels is a problem which has occupied the attention of physical chemists since the inception of colloid chemistry, and even before Graham had introduced the distinction between colloid and crystalloid. Frankenheim [36] in 1835 and von Nägeli [37] in 1858 concluded that jellies were two-phased and that the solid phase was crystalline. This view has been supported by von Weimarn [38] and Levites,[39] and is at present championed by Bradford.[40]

Bütschli [41] introduced the idea that there were definite pores in a jelly, and van Bemmelen [42] extended this conception to the postulation of a " cell-like structure of definite form . . . hanging together at certain points, forming a network." This idea of a network structure in gels has been adhered to by many investigators, but from somewhat variant points of view. Hardy [43] concludes from a microscopical study that the solid phase consists of a solid solution of water in gelatin, and the liquid phase a solu-

[36] Frankenheim: "Die Lehre von der Kohäsion," Breslau, 1835.

[37] v. Nägeli: " Pflanzenphysiologischen Untersuchungen," Zurich, 1858.

[38] v. Weimarn: *Kolloid-Z.,* 2 (1908), 76, 230, 275, 301, 326.

[39] Levites: *Ibid.,* 2 (1908), 161, 273.

[40] Bradford: " The Physics and Chemistry of Colloids, and Their Bearing on Industrial Questions," Report of a General Discussion by The Faraday and Physical Societies of London, October 25, 1920. H. M. Stationery Office, 1921, p. 44.

[41] Bütschli: " Untersuchungen über Structuren," Leipzig, 1898.

[42] v. Bemmelen: *Z. anor. Chem.,* 18 (1898), 14.

[43] Hardy: *Proc. Roy. Soc.,* 66 (1900), 95.

tion of gelatin in water, and that gelation consists in the separation of the sol into a solid open framework with an interstitial fluid phase. This idea is accepted by Freundlich[44] and Anderson,[45] and in essential respects by Miss Lloyd[46] and Fischer.[47] Wo. Ostwald[48] injected the conception of a two-phase liquid-liquid system, and Bancroft[49] has adhered to this idea.

Procter[50] has discarded the two-phase theory of gel structure and postulated the existence of a solid solution of the exterior liquid in the colloid in which both constituents are within the range of the molecular attractions of the mass. This theory was the result of his findings that in a gelatin acid water system equilibrium resulted from the combination of the gelatin and acid to form easily dissociated salts, and that the osmotic pressure of these salts and the Donnan Equilibrium determined the volume of a swollen jelly. Loeb[51] has carried the idea of Procter to a further explanation of colloidal behavior as described later.

These three schools of thought upon colloid structure represent the present status of the problem. For purposes of classification, although not strictly correct, they may be referred to as the crystalline theory, the colloid theory, and the molecular theory respectively.

The concept of a crystalline structure in gels has been studied by Scherrer,[52] who has made many examinations of gels by means of the Röntgen photograph. He found that certain rigid gels as silicic and stannic acids exhibited well-marked crystalline interference figures in addition to the characteristics of amorphous substances, but in the gel of gelatin the crystalline interference figures were entirely lacking. These different types of gels possess other characteristic dissimilarities. The gel of silicic acid, for example, develops, on drying, pores that are filled with air, and which may be filled by imbibition with a liquid other than the

[44] Freundlich: " Kapillarchemie," Leipzig, 1909.

[45] Anderson: *Z. physik. Chem.,* **88** (1914), 191.

[46] D. J. Lloyd: *Biochem. J.,* **14** (1920), 147.

[47] Martin Fischer: "Soaps and Proteins," New York, 1921.

[48] Wo. Ostwald: *Arch. ges. Physiol.,* **109** (1905), 277; **111** (1906), 581.

[49] W. D. Bancroft: "Applied Colloid Chemistry," New York (1921), 239, 242.

[50] H. R. Procter: *J. Chem. Soc.,* **105** (1914), 313.

[51] Jacques Loeb: *J. Gen. Physiol.,* **3** (1921), 827; **4** (1921–22), 73, 97, 351.

[52] P. Scherrer: *Nachr. Kgl. Ges. Wiss. Göttingen* (1918), 96.

original solvent. The elastic gels such as gelatin do not develop such pores, and the dried gel will not imbibe a foreign liquid, as, for example, benzene. Harrison [53] has even succeeded in obtaining spherical coagulation-forms of starch which strongly resemble the so-called spherites that were obtained by Bradford from gelatin, but these are not regarded as crystalline.

The theory of Procter, while explaining adequately the swelling phenomena of gelatin, does not account for other colloidal behavior, as viscosity fluctuations with time, syneresis, or the process of gelation itself.

The net structure hypothesis meets with a number of objections. Of not least importance is the failure of its proponents to account for the existence of such a structure. In the sol form, they say, the structure does not exist; in the gel form it does exist. What has brought about the change and why was it produced? The sudden appearance of structure must be accounted for.

Again, they affirm by this theory that the jelly consists of a sponge-like or honeycomb structure consisting of gelatin as a continuous solid or semi-solid phase, and water (containing inorganic ions and some gelatin molecules in solution) as the dispersed phase. If this were true it should not be difficult to extract the water by moderate pressures, but this cannot be done. Reinke [54] has pointed out that at a pressure of 41 atmospheres the gel of *Lamineria* increases in volume by the absorption of water 16 per cent., and at one atmosphere 330 per cent. Posnjak [55] has shown that at 377 cm. of mercury gelatin gel increases in volume nearly 100 per cent., while at 38 cm. the increase is over 250 per cent. Quincke [56] and Hatschek [57] have shown that a volume contraction accompanies the swelling of gelatin to the extent of nearly two per cent., and Widemann and Ludeking [58] have reported that 5.7 gram-calories of heat are liberated by the swelling of one gram of gelatin. These facts are not explained

---

[53] N. Harrison: *J. Soc. Dyers and Cols.*, **32** (1916), 32.

[54] Described by Hatschek: "Introduction to the Physics and Chemistry of Colloids," London, 1913, 56.

[55] Posnjak: *Kolloidchem. Beihefte*, **3** (1912), 417.

[56] Quincke: *Arch. ges. Physiol.*, **3** (1870), 332.

[57] Hatschek: *Lib. cit.*, 55.

[58] Widemann and Ludeking: *Ann. Physik.*, N. F. **25** (1885), 145.

by the assumption that gelatin swells, like a sponge, by the imbibition of water into the porous structure of the gel.

It should also be urged that diffusion and conductivity take place primarily through the continuous phase and not the dispersed phase of a gel, and if the development of the structure in the gel necessitates the assumption of a reversal of phase, as assumed by Fischer [59] and others, it is difficult to understand the nearly identical degrees of diffusion and of conductivity exhibited by the sol and the gel forms, as pointed out by Graham [60] and by Arrhenius [61] respectively.

It appeared to the writer of the highest importance to a complete understanding of the structure of gels that the sols should be studied also, and that the several conditions affecting the change from the one into the other be clearly defined. This equilibrium was investigated by two series of experiments.[62]

(To be Concluded.)

The Forced Convection of Heat from a Pair of Fine-heated Wires. J. S. G. THOMAS. (*Phil. Mag.,* February, 1922.)—A form of anemometer is in course of development in London in which a pair of electrically heated, parallel wires are immersed in the stream of gas. The velocity of flow is deduced from the change of temperature or consequent change of resistance caused by the motion of the gas. The present paper displays some interesting results in this connection. When the wires, placed perpendicular to the direction of flow and in a plane containing the axis of the pipe and traversed by fixed currents, were kept separated by a certain range of distances, then the resistance of the down-stream wire first fell as the speed of flow increased, then rose again to its value with the gas, air in this case, at rest, passed beyond the original value, reached a maximum, sank to the original value once more, and after this continued to sink, no matter how much the velocity was increased. There were thus two different speeds at which the resistance of the wire had the same value as with the gas at rest. With a different interval between the wires there was but one such speed and with still a different interval no similar speed existed at all. The temperature of the down-stream wire is determined by the loss of heat due to the stream of air and to the heat carried to it from the other wire. Of course eddies in the gas contribute their effect also.

G. F. S.

---

[59] Martin Fischer: *Loc cit.*

[60] Thomas Graham: *Cit. sup.*

[61] S. Arrhenius: *Cit. sup.*

[62] R. H. Bogue: " The Sol-Gel Equilibrium in Protein Systems," and " The Structure of Elastic Gels," *J. Am. Chem. Soc.,* on press.

826 CURRENT TOPICS. [J. F. I.

Observations and Experiments on the Occurrence of Spark Lines. G. A. HEMSALECH and A. DE GRAMONT. (*Phil. Mag.,* February, 1922.)—Years ago Sir Norman Lockyer noticed that certain spectrum lines not produced at all in the flame and appearing only feebly in the arc sprang into brightness when a strong condenser spark was made the source of light. Such lines are known as "enhanced" or "spark" lines. Under certain conditions spark lines have been seen in the inner cone of the gas flame. There has been, moreover, much uncertainty as to their origin. They have been ascribed to high temperature, to electro-luminescence and to ionic collision. After the present investigators have developed a simple method of getting arc spectra with such metals as tin and lead, they find that lowering the ionization of the arc by blowing air through it causes the spark lines to appear. These lines, however, disappear when the cathode is white-hot carbon. "They are brought out prominently, on the other hand, when the electrodes are cooled down to –190° C. by immersion in liquid air." "The whole of our experiment points to the fact that spark lines are emitted when electric currents are passed through media (vapours or gases) which possess a low degree of ionization. Since such a process involves the application of powerful electric forces giving rise to the establishment of high-potential gradients in the medium concerned, we are finally lead to conclude that the emission of spark lines is connected with the existence of strong electric fields. A simple consideration shows indeed that for small pole distances the electric field within the arc-gap can be very great even with a small potential difference. Thus, for a pole distance of 0.05 mm. the intensity of the electric field with an applied potential 110 volts is equal to 22,000 volts per cm. As we have shown in the course of this research spark lines are strongly emitted by the arc only while the distance between the electrodes is precisely very small." G. F. S.

Surface Tension of Soap Solutions for Different Concentrations. A. L. NARAYAN and G. SUBRAHMANYAM. (*Phil. Mag.,* April, 1922.)—Marangani drew the conclusion from the rise of soap solutions in capillary tubes that the surface tension is for wide ranges of concentration independent of the strength of the solution. White and Marden, on the other hand, have given out as a result of their experiments that the surface tension does change with concentration in the ratio of 2 to 1 or even more. The present investigators used two methods, ascent in capillary tubes and measurement of the excess of pressure within a soap bubble. They have established by the agreement of both methods that the surface tension has the same value for a saturated solution and for all solutions down to those containing only 2 or 3 per cent. as much soap as the saturated solution. For very dilute solutions, however, the surface tension grows larger, beginning when there is .23 g. of soap per 100 c.c. of solution. G. F. S.

NOTES FROM THE U. S. BUREAU OF STANDARDS.*

THERMAL STRESSES IN CHILLED IRON CAR WHEELS.[1]
By G. K. Burgess and R. W. Woodward.

[ABSTRACT.]

FOR over half a century most of the freight cars in this country have been equipped with chilled iron car wheels. These wheels have given general satisfaction, even under the present existing conditions of greater speeds and increased stresses due to the use of heavier wheel loads. It has been observed, however, that failures of chilled iron wheels occur occasionally at the foot of long, steep grades, and the greatest cause of such failures appears to be the heating of the tread by the prolonged application of the brake shoe.

The difference in temperature between the tread and the hub induces stresses in the wheel, which in some cases are sufficient to cause cracking and failure, possibly resulting in the derailment of the car under which the wheel is placed. A conception of the seriousness of this type of failure may be obtained from the report of one of the large railroad systems wherein it is indicated that during a test covering a period of approximately seven months, about 19 per cent. of the chilled iron wheel failures occurred in the plate, which is the type of failure resulting from thermal stresses.

A method was developed at the Bureau of Standards for testing car wheels in the laboratory under conditions approximating severe service. The wheels were heated by passing an electric current through a band of iron encircling the wheel; the resulting stresses were calculated from strain gage measurements after correcting for thermal expansion.

Twenty-eight wheels of varying weights and design from three manufacturers were tested in this manner, of which sixteen failed by cracking in the plate. Although the total number of wheels tested is too small to draw any definite conclusions, the results seem to point to the following generalities which should be confirmed by a greater number of tests:

I. The maximum stresses developed are very close to the

* Communicated by the Director.
[1] Technologic Paper, No. 209.

827

tensile strength of the cast iron and are some function of the
strength of the iron.

2. The maximum tensile stresses occur in a radial direction
near the junction of the double plates in the M.C.B. or Washburn
type of wheel. In the arch plate type the maximum stress is some-
what nearer the hub. This seems a desirable condition in that it
lies in the region where it is counteracted by the strains due to
forcing the wheel on to its axle.

3. The stress in a tangential direction on the outer face and also
the stress in both the radial and tangential directions on the bracket
side of the wheel are relatively small when compared with those
in a radial direction on the outer face of the wheel.

4. By proper distribution of metal in the single plate type of
wheel there would appear to be a possibility of securing a wheel
more capable of meeting service requirements.

5. With identical rates of heat input the heavier weight wheels
withstand the effect of tread heating with less strain than the
lighter wheels.

6. The tests also lead one to believe that the operating condi-
tions to which wheels are subjected may be as important a
factor in the safety of the wheel as are the problems arising in
their manufacture.

INTERFERENCE METHODS FOR STANDARDIZING AND TESTING PRECISION GAGE BLOCKS.[2]

By C. G. Peters and H. S. Boyd.

[ABSTRACT.]

PRECISION gages, which are blocks of metal (usually steel),
having two opposite faces plane, parallel, and a specified distance
apart, are used in the shop as reference end standards for checking
micrometers and other measuring instruments, and also as distance
pieces or size blocks for precise mechanical work. The extensive
use of precision gages necessitated by the small tolerances allowed
in the manufacture of interchangeable machine parts has required
more accurately determined end standards and more rapid and pre-
cise methods for comparing gages with these standards than have
been previously available.

Since comparisons of end standards with line standards by
means of micrometer-microscopes and of precision gages with end

-----

[2] Scientific Papers, No. 436.

standards by means of contact instruments are subject to appreciable errors, methods which make use of the interference of light waves were used in making these measurements. With the interference methods described in this article, the planeness and parallelism errors of precision surfaces can be measured, and the length of standard gages can be determined by direct comparison with the standard light waves with an uncertainty of not more than a few millionths of an inch. The errors of other gages can be determined by comparison with these calibrated standards with equal precision. This process makes the standard light waves, which have been determined to 1 part in 4 or 5 million relative to the international meter, the standards of length for this work.

The apparatus used for calibrating standards and comparing other gages with these standards is illustrated by line drawings and thoroughly explained.

ELECTROMOTIVE FORCE OF CELLS AT LOW TEMPERATURES.[3]

By G. W. Vinal and F. W. Altrup.

[ABSTRACT.]

THE practical importance of a knowledge of the electromotive behavior of dry cells and storage batteries at low temperatures has arisen from their use in the Arctics and at high altitudes. Measurements on dry cells and storage batteries cooled to —72° C. by carbon dioxide snow and to —170° C. by the use of liquid air were made. The Gibbs-Helmholtz equation was applied to the observations, and excellent agreement between theory and observation was found. At the lowest temperatures high values of voltage were sometimes observed, and the polarity was often reversed. A possible explanation based on the Nernst equation is given.

CONSTRUCTION AND OPERATION OF A SIMPLE HOME-MADE RADIO RECEIVING OUTFIT.[4]

[ABSTRACT.]

THE apparatus used for the reception of radio messages may be a home-made affair, very simple and inexpensive, or it may be elaborate and expensive. All that is necessary for receiving radio

[3] Scientific Papers, No. 434.
[4] Circular No. 120.

messages is a device for collecting power from incoming radio waves, a suitable circuit " adjusted " or " tuned " electrically to the frequency of the incoming waves, and apparatus for changing the received power into audible sounds.

This Circular describes the method of constructing in the home a very simple and inexpensive receiving outfit from materials which can be easily secured. The cost of the materials need not exceed $10. Satisfactory results have been obtained from sets constructed according to these instructions by persons having no previous experience with radio.

The preparation of this publication had its origin in work undertaken by the Bureau of Standards, in coöperation with the Bureau of Markets and Crop Estimates of the Department of Agriculture, in connection with the broadcasting by radio of Government news and information. This broadcasting service has proved to be very useful to farmers, bankers, dealers, and many others, and a considerable demand arose for information regarding simple receiving equipment.

The five essential parts of a radio receiving station are the antenna, lightning switch, ground connection, receiving set, and telephone receivers. The antenna is the device for collecting power from the incoming waves. The signals received on the antenna are converted into an electric current in the receiving set, and a corresponding sound is produced in the telephone receivers.

The antenna may be a wire about 75 feet long, attached through insulators to buildings or other convenient supports.

The lightning switch protects the receiving set from damage by lightning. It may consist simply of a small single-pole, double-throw battery switch. The lightning switch connects the antenna directly to ground when the receiving station is not in use. When the antenna and connection to the ground are properly made and the lightning switch is closed, the antenna acts as a lightning rod and is a protection to the building.

The principal part of the station is the " receiving set." The outfit described in this Circular consists of two parts, the " tuning coil " and the " crystal detector," and in more complicated sets still other elements are added.

The " tuning coil " consists of a coil of wire which may be wound on a cylindrical cardboard tube such as an oatmeal box. The coil of wire is attached at a number of points, from which

connections are made to the points of a multiple-point switch. The adjustment or " tuning " of the receiving set to the frequency or wave-length of the incoming waves is made by adjusting the position of the switch handle so that connection is made with varying numbers of turns to the tuning coil.

The crystal detector consists of a small piece of selected galena or other tested mineral, with suitable mounting.

The tuning coil, switch, and crystal detector are mounted on a wooden base.

The telephone receiver must be purchased. A single telephone receiver may be used, but a pair will give better results.

The outfit described in this Circular will enable anyone to hear radio code messages or music and voices sent from a medium power transmitting station within an area about the size of a large city, and from high power stations within 50 miles, provided that the waves used by the sending stations have a wave frequency between 500 and 1500 kilocycles per second (that is, wave-lengths between 600 and 200 metres). This equipment will not receive uninterrupted continuous waves. Occasionally, much greater distances can be covered, especially at night. Sets constructed according to these instructions have given clear reception of music transmitted by radio telephone from stations 300 miles distant.

AN IMPROVED METHOD FOR PREPARING RAFFINOSE.[6]
By E. Clark.

[ABSTRACT.]

FIVE kilograms of coarsely ground cottonseed meal are thoroughly moistened with two litres of water and allowed to stand over night. It is then loosely packed in a cylindrical percolator, and sufficient water added to saturate the meal and leave a stratum above it. When the liquid begins to run from the percolator, more menstrum is added, from time to time, until a sample of the percolate after defecation with dry basic lead acetate, has an optical rotation of not more than $1°$ in a 2 dm. tube.[6] The process is then

---

[6] Scientific Paper, No. 432.

[6] As there are substances in the meal which are extracted much more slowly than the sugar, and which cause difficulty in the subsequent steps as well as give an inferior product, it is essential to obtain a quite rapid percolation, consuming not more than 30 to 35 minutes; it is not expedient to carry the extraction beyond where the optical rotation of the liquid is less than $1°$ in a 2 dm. tube.

stopped, and the percolate is treated with a solution of basic lead acetate until no more precipitate is formed. The yellow precipitate is filtered off upon large folded filters and finally washed on the filter with a little water. The filtrate and washings are freed from the excess of lead with oxalic acid. The filtrate from the lead oxalate is measured, and the optical activity of the liquid determined. It is then made distinctly alkaline to litmus with sodium hydroxide. The precipitate thus formed flocks out and settles to the bottom of the vessel in a few minutes. The supernatant liquid is next filtered through a Buchner funnel provided with a thin layer of decolorizing carbon on filter paper. When all has passed through, the precipitate is placed on the filter and drained.

The raffinose is next removed from the solution by forming the insoluble calcium raffinosate. To conveniently accomplish this the liquor is cooled to 10° C. or lower, placed in a suitable container, and rapidly stirred with a mechanical stirring device. As it is being agitated a quantity of powdered active lime, preferably 200 mesh, but not coarser than 100 mesh, sufficient to precipitate all the sugar is slowly sifted in. After all has been added, the stirring is continued for about five minutes. If the lime is active and the optical activity of the solution is calculated to raffinose hydrate with a specific rotation of about 105°, 1 gram of lime to 1 gram of raffinose is sufficient for complete precipitation. However, unless the activity of the lime is known, it is advisable to test the liquid to see if all the sugar has been removed; if not, more lime should be added. The calcium raffinosate is filtered off, washed by grinding up to a smooth paste with 2½ litres of cold lime water, and again filtered.

It is next carbonated to neutrality. The device illustrated in the article was used for this purpose. The cake of raffinosate is placed in a deep, narrow can of about 8 litres capacity and filled three-fourths full of water at 50° C., and a lively stream of carbon dioxide is passed through the apparatus while it is being turned about 1500 r.p.m. In this way the lime is neutralized in 4 or 5 minutes without any loss of CO_2. The solution is filtered while hot, and the precipitate is washed by grinding up with two litres of water and again filtering. The combined liquors are evaporated under diminished pressure to 70 to 75 per cent. total solids and warmed to about 60° C. To this syrup 95 per cent. ethyl alcohol is

added just to saturation. The alcoholic solution is then warmed on the water bath to about 60° C. and filtered through a small Buchner funnel in which has been placed a mat of washed asbestos. The filtrate is seeded and placed in the ice box to crystallize.

The raffinose is filtered off from the mother liquor, washed first with 80 per cent., then 95 per cent. alcohol, and dried. The yield is from 2.3 to 4 per cent. of raffinose, depending upon the meal used. The crude sugar thus prepared is quite pure, containing only from 0.06 to 0.08 per cent. ash.

To purify crude raffinose a 40 per cent. solution (anhydrous sugar) is made by dissolving it in distilled water at 70° C. The warm solution is filtered through a mat of asbestos and placed in the ice box to crystallize. The crystals are freed from mother liquor, washed with 80 per cent., then 95 per cent. alcohol, and dried.

An alternative method of recrystallization is to concentrate the above 40 per cent. solution under reduced pressure to 70 per cent. total solids, warm to 70° C., and add two volumes of 95 per cent. alcohol with constant stirring. Crystallization begins almost at once and is complete in a few hours. The crystals are filtered off, washed with 95 per cent. alcohol, and dried.

Fluorescence and Photo-chemistry. R. W. Wood. (*Phil. Mag.*, April, 1922.)—"Though it has been known for some time that many fluorescent solutions are bleached by the action of light, Perrin appears to have been the first to definitely associate fluorescence with chemical change and to regard the light emitted by fluorescent substances as due to the 'flashes' of exploding molecules." At his summer laboratory, East Hampton, Long Island, in 1919 and 1920, Professor Wood subjected sundry fluorescent solutions to a beam of sunlight concentrated by a lens of short focus and 6 inches in diameter. He thus got sufficient quantities of the products resulting from the action of light to enable him to examine their optical and chemical properties. "Usually the decomposition of the fluorescent substance by the action of light yields a colored non-fluorescent substance which is bleached by the further action of light to a colorless solution." Photographs were made of the absorption spectra of the original solutions and of the solutions after the action of light. "Fluorescein (uranine), for example, which is lemon-yellow by transmitted light, is changed into a non-fluorescent compound (photofluorescein), which is orange-red, with an absorption band of a totally different form." "The time required to effect the change varies with the nature of the substance: eosine is completely changed in two or three minutes, while rhodamine in the same concentration

requires several hours." The effect of light on rhodamine varies with the solvent. In aqueous solution a bleaching effect takes place without the formation of an intermediate colored body, but in alcoholic solution such an intermediate body is developed which fluoresces with green light, whereas the rhodamine has orange-red fluorescence. Certain specimens of rhodamine almost cease to fluoresce at 100° C., while eosine manifests no temperature effect.

Careful experiments showed that, at least in the case of fluorescein, the intensity of the fluorescent light is directly proportional to the intensity of the exciting light.

The Johns Hopkins physicist sought to test Perrin's hypothesis that fluorescence is due to molecular disintegration. There are two cases in which fluorescent substances do not fluoresce when exposed to light: a in general when in too concentrated solutions, b in particular when certain specimens of rhodamine are heated. A strong solution of eosine was put in concentrated sunlight. It showed no trace of fluorescing nor did it suffer any change by its exposure to light, while a dilute solution both emitted fluorescent light and underwent change. These results tend to show that fluorescence and chemical change are parallel processes. Next two similar solutions of rhodamine were exposed to light equally, but one was kept at 100° C. The cold solution emitted much brighter fluorescent light than the other, yet decomposition was equal in the two solutions. Thus the outcome of the two experiments is contradictory. The first favors Perrin's views. The second seems to negative them.

The change produced in fluorescent solutions is not in proportion to the energy absorbed from the incident light. Light of great intensity acting for a short time produces more change than a weaker light acting for an equivalently longer time.

The announcement is made that for future experiments a mirror is available having a 32-inch aperture and focal length of 18 inches, which produces so intense a concentration of sunlight as to melt platinum foil instantly. G. F. S.

Potash as a By-product in the Blast Furnace Industry.— WILLIAM H. ROSS and ALBERT R. MERZ, of the United States Bureau of Soils (*Jour. Ind. Eng. Chem.*, 1922, xiv, 302–303), report a study of the potash content of iron ore, limestone, coke, and blast furnace slag. The potash content of iron ore ranged from 0.05 per cent. to over 2 per cent., the average content was 0.19 per cent. The average potash content of limestone was 0.20 per cent., of coke 0.24 per cent. and of slag 0.56 per cent. In the blast furnace, 5.6 pounds of potash (K_2O) are lost by volatilization for each short ton of pig iron produced. During the year 1920, it is estimated, 115,000 short tons of potash were lost in this manner. In order to recover this potash, a dry system of purification of the furnace gases will be necessary. The collected dust would be of value as a source of potash, especially in case of an emergency. J. S. H.

NOTES FROM THE RESEARCH LABORATORY
EASTMAN KODAK COMPANY.*

THE USE OF ARTIFICIAL ILLUMINANTS IN MOTION PICTURE STUDIOS.[1]

By L. A. Jones.

THE paper deals with the effects of various artificial and natural illuminants upon the photographic material and also with the action of these light sources upon the retina of the eye. In the introductory portion, some space is devoted to a discussion of the nomenclature and terminology used in dealing with the subject matter. The well-known photometric terms are defined and classified and several photographic units parallel in meaning to the photometric units are defined. The new terms defined in this paper are "photic flux," "photoibility," "photocity," "photic efficiency," and "photon." The last word is proposed as a name for the unit of photic flux and is defined as a photographic equivalent of the lumen. Some space is devoted to the relative photographic and visual efficiency of various artificial illuminants and several tables of data relating to the subject are given. The transmission characteristics of photographic lenses are treated and quantitative data relative to this are given. A method of calculating the illumination required in the studio in order to obtain satisfactory exposures with photographic materials of known characteristics is outlined.

THE GLOSS CHARACTERISTICS OF PHOTOGRAPHIC PAPERS.[2]

By L. A. Jones and M. F. Fillius.

AT the present time the gloss characteristics of photographic papers are designated by such more or less vague terms as " matte," " semi-matte," " velvet," etc. The desirability of expressing this

---

* Communicated by the Director.

[1] Communication No. 135 from the Research Laboratory, Eastman Kodak Company, and published in *Trans. Soc. Mot. Pic. Eng.*, No. 13, p. 74.

[2] Communication No. 134 from the Research Laboratory, Eastman Kodak Company, and published in *Jour. Opt. Soc. Amer.*, March, 1922, p. 140.

factor more precisely in numerical terms is pointed out. A method of defining gloss in terms of the relative intensity of diffusely and regularly reflected light is outlined. The goniophotometer, an instrument for measuring the distribution of the light reflected from a surface, is described and the method of computing the gloss of the surface from the readings obtained is outlined. The determination of gloss by this method requires two measurements of the brightness of the surface at different angles. In order to eliminate the errors inherent in such a method, a special instrument called a " gloss meter " was designed and constructed whereby the gloss of any surface may be determined by a single reading. This instrument is described. Gloss measurements on a large number of developing-out papers are given, and the effect upon gloss of various surface treatments of the raw stock is determined. From an analysis of the readings obtained, a tentative numerical definition of the words matte, semi-matte, semi-gloss and glossy in numerical terms is given.

Action of Fuming Sulphuric Acid on Cast Iron and High Silicon Iron.—Apparatus, which is made of cast iron or high silicon iron and is used for the handling of fuming sulphuric acid, frequently cracks from no apparent cause. Heavy pipes, not subjected to any unusual strain, may crack longitudinally with a loud report. T. F. Banigan (*Jour. Ind. Eng. Chem.*, 1922, xiv, 323) has studied the prolonged action of fuming sulphuric acid, known as oleum or 103.37 per cent. sulphuric acid, on a high silicon iron alloy, on amorphous silicon, and on silicon carbide. Both the alloy and the silicon were attacked at room temperature with the production of silicon dioxide. The silicon carbide was not attacked even at a temperature of 100° C. Amorphous silicon was not attacked by 96 per cent. sulphuric acid acting for one week at a temperature of 100° C. Hence the sulphur trioxide in the fuming acid readily oxidizes silicon, either free or alloyed with iron. High silicon alloys are rapidly corroded by the fuming acid since the silicon is oxidized to voluminous silica (silicon dioxide), and a fresh surface is continually exposed. In cast iron and malleable iron, the sulphur trioxide penetrates the pores, oxidizes the silicon, and produces silica which occupies a larger volume than did the silicon from which it was derived. An internal strain is thereby created, and gives rise to failure of the apparatus. Apparently neither the silicon carbide nor the carbon in the casting has any action on the acid or any responsibility for the failure of the apparatus.   J. S. H.

NOTES FROM THE U. S. BUREAU OF CHEMISTRY.*

POISONOUS METALS ON SPRAYED FRUITS AND VEGETABLES.[1]

By W. D. Lynch, C. C. McDonnell, J. K. Haywood, A. L. Quaintance, and M. B. Waite.

[ABSTRACT.]

THE amounts of arsenic, lead and copper remaining on mature fruits and vegetables which have been sprayed according to various schedules were determined in the Bureau of Chemistry.

Because of overspraying or late spraying, comparatively large quantities of spray residues were found in some cases. This emphasizes the importance of spraying according to the schedules recommended by the Bureaus of Entomology and Plant Industry.

The extent of the reduction of spray residues on the mature fruit and vegetables by washing and wiping them was determined by a series of analyses before and after such treatment.

When peeled, sprayed fruits and vegetables contain essentially the same amounts of arsenic, lead, and copper as the unsprayed products, indicating that practically all of the spray residues can be removed by peeling.

When fruits and vegetables are sprayed in accordance with the schedules recommended by the Bureaus of Entomology and Plant Industry, but little of the material used remains on the fruit or vegetable at harvest time.

DOMESTIC AND IMPORTED VERATRUM (HELLEBORE), *VERATRUM VIRIDE* AIT., *VERATRUM CALIFORNICUM* DURAND, AND *VERATRUM ALBUM* L.[2]

By Arno Viehoever, George L. Keenan, and Joseph F. Clevenger.

[ABSTRACT.]

MEANS for the differentiation of the rhizomes and roots of domestic Veratrum (*Veratrum viride*), imported Veratrum (*Veratrum album*), and *Veratrum californicum,* a form hitherto not studied histologically, have been devised.

---

* Communicated by the Acting Chief of the Bureau.
[1] *U. S. Department of Agriculture Bulletin 1027*, issued April 17, 1922.
[2] Published in *J. Am. Pharm. Assoc.,* 10 (1921): 581; 11 (1922): 166.

Botanical.—The endodermal cells, forming a sheath in the rhizome and root, the cells of which show different thickenings of the inner tangential and radial walls, are the main differentiating characteristics. The calcium oxalate raphide bundles occurring in both rhizome and root, differing in length in the different species, were found to be more or less characteristic. Calcium oxalate raphides in the leaf scales attached to the rhizomes of *Veratrum viride* and *Veratrum album* are longer than those in the rhizomes and roots of these species. The epidermal cells of the roots also differ in size, being smallest in the case of *Veratrum viride,* larger in *V. album,* and still larger in *V. californicum.* These characteristics vary greatly, showing a tendency to overlap in some instances.

Chemical.—The alkaloids of *Veratrum album* do not differ much from those of *Veratrum viride.* The alkaloid content in both species varies within the same limits, so that no differentiation of species is possible on this basis. Microsublimation indicates close chemical relationship, but does not permit of ready differentiation. The close botanical and chemical relationship of *Veratrum viride* and *Veratrum album* justifies the adoption of the same standards for the medicinal material obtained from both species. The standards suggested for the medicinal drugs are at least 1 per cent. for alkaloids and not more than 8 per cent. total nor more than 4 per cent. acid-insoluble ash.

General.—The present market quotations indicate that *Veratrum album* and *Veratrum viride* are considered of equal value. No data, however, as to the relative value of *Veratrum viride* and *Veratrum album,* definitely identified as such, appear to be available. The means pointed out for their histological differentiation should make possible comparative studies of the plants as found in the market. Their relative values as therapeutic agents and as insecticides may be thus established.

FAKE SAFFRON.[3]
By Arno Viehoever and J. F. Clevenger.
[ABSTRACT.]

The appearance of some material imported from Spain was skillfully changed, so that it might pass for saffron. It resembled Crocus in appearance and in flavor. Close inspection, however, showed that instead of the stigmas characteristic of Crocus, tubular

---

[3] Published in *J. Am. Pharm. Assoc.,* **10** (1921): 671.

florets characteristic of a number of the Compositæ were present. This substitution was complete, no stigmas of Crocus being present.

The substitute was identified as a species of *Onopordon* closely related to *Onopordon sibthorpianum* Boiss and Heldr. The materials had been dyed with a mixture of Tartrazine and commercial Ponceau 3 R. It was weighted with a mixture of at least 5 per cent. potassium nitrate and borax. About 4 per cent. glycerin was also present. The material was evidently flavored with saffron oil.

Corrosion of Iron and Steel.—This important subject has been extensively studied, and the present state of opinion with a summary of much of the literature was presented in a communication by A. Pickworth, M.Sc., to the North-east Coast Institution of Engineers and Shipbuilders (Newcastle-upon-Tyne). Attention is called to the great waste that such corrosion involves and to the several theories of causes that have been proposed. It appears that iron does not rust in water containing only oxygen, but the presence of some substance giving rise to ionized hydrogen is required. Under ordinary conditions the active substance is carbonic acid, but, of course, other acids may be present, especially those produced by the oxidation of the organic matters of soil. The air of built-up areas is almost always contaminated with sulphur acids, and iron rust in such places usually contains notable amounts of sulphates. Electric conditions have an important bearing on corrosion. A difference of potential of the area exposed to water will determine the development of oxidation at certain points. Doctor Friend has recently investigated the subject with much care and offers a somewhat new theory. The oxidation of iron in contact with liquid water is catalytically accelerated by the ferric hydroxide hydrosol being alternately reduced by contact with the iron and oxidized again by contact with atmospheric oxygen.

Iron, in any of its forms, is attacked by a weak solution of carbonic acid, forming ferrous carbonate, which in the presence of free oxygen is converted into ferric hydroxide, thus again liberating carbon dioxide, which reforms the acid condition with the water, capable of repeating the process. It is evident that the small amount of carbonic acid normally in water may carry on the oxidation continually. Some years ago, a process for water purification was based on this principle. Ferric hydroxide has a high adsorptive power for organic matters, but is active only in the fresh colloidal state. By agitating water with iron scrap, fairly free from oil and rust, a green turbidity appears which soon changes to red. If now the water is filtered, a great deal of the organic matter will be held by the ferric hydroxide, which, of course, will be retained on the filter.

It has also been claimed that if bright iron is immersed in water

practically free from oxygen and carbon dioxide, a minute amount of colloidal iron will form which will immediately oxidize if the water is allowed to come in contact with air.

Rust commonly met with in steel structures consists chiefly of iron combined with oxygen and water, forming a ferric hydrate, and has usually the familiar reddish brown color, but the true color is often disguised by the presence of deposited dust and traces of paint.

The product of corrosion is bulky, porous and hygroscopic. These properties tend to accelerate rusting, as the corroding influences in the form of vapors or liquids are attracted by and readily pass through the existing layer. Moreover, iron rust is electro-negative to iron, and furnishes innumerable local Voltaic couples in the presence of an electrolyte, which accelerate corrosion. Here, again, it will be observed that the hygroscopic nature of the rust constitutes a favorable channel for the electrolytic action. Upon removing apparently dry flakes of ferric oxide from a structure, a layer of moisture is often found between them and the steel. Thus, it can be understood that when rusting has once commenced it will readily proceed. Doctor Andrews showed that 50 per cent. more rust was deposited the second year compared with the first. It is unfortunate that the oxide, which forms on the surface of steel or iron assists in the process of rusting while the oxide coatings of other less commonly used metals such as aluminium, lead and copper, form a layer which protects the metal below.

It is recorded that some rejected plates from the Britannia Bridge, left unprotected upon a wooden platform exposed to the wash and spray of the sea, at the end of two years were so corroded that they could be swept away with a broom. They had an original thickness of seven-sixteenths to three-fourths of an inch. Basing calculation on the amount of corrosion which had taken place in the steel of the Britannia Bridge which had been kept well coated and clean, Baker found that it would take about 1200 years to corrode the plates entirely. Roughly, the plates, which are well looked after, will last 600 times as long as neglected plates. These facts are mentioned to show that so far as corrosion is concerned, the serviceable life of a structure or vessel can be extended enormously by careful attention to cleaning and recoating.   H. L.

Crystal Structure of Complex Cyanides.—ROSCOE G. DICKINSON, of the California Institute of Technology (*Jour. Am. Chem. Soc.*, 1922, xliv, 774–784), has determined the crystal structure of certain complex or " double " cyanides by means of spectral photographs and unsymmetrical Lane photographs. The salts studied were potassium zinc cyanide, potassium cadmium cyanide, and potassium mercuric cyanide. These complex cyanides were found to have the same crystal structure as the minerals magnetite (ferrous ferrite, Fe_3O_4) and spinel (magnesium aluminate, $MgAl_2O_4$).   J. S. H.

THE FRANKLIN INSTITUTE.

HALL OF THE FRANKLIN INSTITUTE,
PHILADELPHIA, May 17, 1922.

DR. WALTON CLARK, President of the Institute, *in the Chair.*

By consent the reading of the minutes of the previous meeting was dispensed with.

The Chairman announced that the annual presentation of The Franklin Medal, the Institute's highest award, in recognition of distinguished scientific and technical achievements, would be made and recognized Dr. Joseph S. Ames, Professor of Physics, the Johns Hopkins University, Baltimore, Maryland, who gave an account of the work of Sir Joseph John Thomson, Trinity College, Cambridge, England, recently awarded The Franklin Medal in recognition of " The immeasurable service he has rendered to the world as teacher and leader of thought in that domain of science, especially related to a fundamental knowledge of electricity and the constitution of matter."

Mr. R. L. Craigie, First Secretary of the British Embassy, Washington, District of Columbia, was then presented to the Chairman and received from him The Franklin Medal, accompanying Certificate and Certificate of Honorary Membership in the Institute, awarded to Sir Joseph John Thomson. Mr. Craigie conveyed the thanks of his government for the honors conferred upon his distinguished countryman.

Dr. Onward Bates was then recognized and described the work of Dr. Ralph Modjeski, of New York City, who had also been awarded The Franklin Medal in recognition of " His signal achievements as a designer and builder of structures, mainly bridges, many of them epoch-marking in the history of the engineering profession, beautiful as well as useful, involving on the part of the designer vision, courage and technic of the highest order."

Doctor Modjeski was then presented to the Chairman and received from him The Franklin Medal, accompanying Certificate and Certificate of Honorary Membership in the Institute. Doctor Modjeski expressed his thanks for the high honors conferred upon him.

The President then requested Mr. Coleman Sellers, Jr., Vice-president of the Institute, to take the Chair. Mr. Sellers recognized Mr. Nathan Hayward, who presented to the Institute, on behalf of its Board of Trustees, Board of Managers and Officers, a portrait of Dr. Walton Clark, painted by Mr. Lazar Raditz. Mr. Sellers accepted the portrait for the Institute.

The paper, "An Electron Theory of Solids," by Sir Joseph John Thomson, was read by Dr. Joseph S. Ames.

Doctor Modjeski then read his paper " Bridges—Old and New."

Adjourned.

R. B. Owens,
Secretary.

(A full account of the meeting will appear in a later issue of the Journal.)

COMMITTEE ON SCIENCE AND THE ARTS.

(Abstract of Proceedings of Stated Meeting held Wednesday, May 3, 1922.)

HALL OF THE INSTITUTE,
PHILADELPHIA, May 3, 1922.
DR. JAMES BARNES *in the Chair.*

The following reports were presented for final action:

No. 2780: Rich System of Detecting and Extinguishing Marine Fires. The Certificate of Merit to Walter Kidde and Company, Incorporated, of New York.

No. 2786: Postage Meter. The Certificate of Merit to Mr. Arthur H. Pitney, of Stamford, Connecticut.

The following report was presented for first reading:

No. 2784: Oxidation of Benzene to Maleic Acid.

R. B. Owens,
Secretary.

SECTIONS.

Section of Physics and Chemistry.—A meeting of the Section was held in the Hall of the Institute on Thursday evening, April 6, 1922, with Dr. H. J. M. Creighton in the Chair. The minutes of the previous meeting were approved as read.

E. W. Washburn, Ph.D., of the Department of Ceramics of the University of Illinois delivered a lecture on " Physical Chemistry and Ceramics." The application of the methods of physical chemistry to the solution of various problems in the field of ceramics was described. The lecture was illustrated by lantern slides. The communication was discussed.

On motion of Prof. W. O. Sawtelle, a rising vote of thanks was extended to Doctor Washburn. The meeting then adjourned.

JOSEPH S. HEPBURN,
Secretary.

Section of Physics and Chemistry.—A meeting of the Section was held in the Hall of the Institute on Thursday evening, April 13, 1922, at 8 o'clock, with Dr. Arthur W. Goodspeed in the Chair. The minutes of the previous meeting were approved as read.

K. T. Compton, Ph.D., Professor of Physics in Princeton University, Princeton, New Jersey, delivered a lecture on " The Physics of the Three-

Electrode Bulb." The Edison and thermionic effects were demonstrated; the properties of thermionic currents, the theories of thermionic emission, and the characteristics of evacuated and gas-filled bulbs were described. The lecture was illustrated by means of lantern slides and experiments.

The communication was discussed; a vote of thanks was extended to Doctor Compton, and the meeting adjourned.

<div align="right">

Joseph S. Hepburn,
Secretary.

</div>

Mechanical and Engineering Section.—A meeting of the Section was held in the Hall of the Institute on Thursday evening, April 27th, at 8 o'clock, with Mr. A. W. Gibbs in the Chair.

The paper of the evening was presented by Dr. Frank J. Sprague, President of the Sprague Safety Control and Signal Corporation, New York City. The speaker described railroad operation of the United States which is mainly carried on under three methods of control—train orders, manual blocking and automatic block signals—the latter of which is the most modern and adds measurably to the safety and efficiency of operation. Despite these facts, up to the present is has been adopted on less than one-third of the trunk line mileage of the country.

This system is based upon the division of the tracks into blocks of various lengths, each fully or partly insulated from the other and supplied with current at its far end to normally energize a relay at the near end. These relays—active or not according as the blocks are occupied—control a system of motor-operated wayside signals inter-connected in such manner that they are made to show "danger," "caution" or "clear" indications, according to track conditions.

But these signals are after all but directional in character, and to be effective must be seen, understood and obeyed by the engineer. Experience has shown that these three essential conditions often are not met, from any one of many evident causes, and as a consequence disastrous end-on collisions not infrequently occur.

To overcome this defect in the present system of railroad operation many kinds of "automatic stops" and "automatic train controls" have been proposed, designed to protect the train in the event of failure of the engineer, but a satisfactory solution of the problem, that is, one which while affording ample protection will at the same time leave the engineer under all normal conditions in control of his train is a difficult one.

The present paper dealt with a specific development based upon the use of track magnets under control of the signal relay, to establish cab signals and to initiate the required braking, which system is being subjected to intensive tests on the New York Central Railroad. This system is based upon the same tract fundamentals as is the automatic signal system and can be used either independently of it, that is with cab signals only, or in connection with the wayside signals to combine them and the braking system of the train.

After a brief discussion a unanimous vote of thanks was extended to the speaker and the meeting adjourned.

<div align="right">

Alfred Rigling,
Acting Secretary.

</div>

MEMBERSHIP NOTES.

ELECTIONS TO MEMBERSHIP.

(Stated Meeting, Board of Managers, May 10, 1922.)

RESIDENT MEMBERSHIP.

MR. SAMUEL SHOBER, Rittenhouse Club, Philadelphia, Pennsylvania.

NON-RESIDENT MEMBERSHIP.

MR. L. E. THOMAS, President, Reading Iron Company, Reading, Pennsylvania.

CHANGES OF ADDRESS.

MR. OLAF ANDERSEN, Norges Geologiske Undersokilse, Kronprinsensgt 2, Kristiania, Norway.

MR. FRANK M. ASHMEAD, The Locust, Atlantic City, New Jersey.

MR. D. B. HEILMAN, P. O. Box 453, Reading, Pennsylvania.

MR. JOHN W. HORNSEY, 2 Whitehall Court, London, S. W. 1, England.

MR. R. QUAYLE, 233 North Harvey Avenue, Oak Park, Illinois.

MR. J. STEPH. VAN DER LINGEN, Department of Applied Mathematics, University of Cape Town, Cape Town, South Africa.

MR. ETHAN VIALL, 7474 Lower River Road, Fernbank, Cincinnati, Ohio.

NECROLOGY.

Mr. Alfred Wolcott Gibbs, Wayne, Pennsylvania.

LIBRARY NOTES.

PURCHASES.

ABRAHAM, KARL.—Steam Economy in the Sugar Factory. 1912.

American Committee on Electrolysis—Second Report. 1921.

BEST, WILLIAM N.—Burning Liquid Fuel. 1922.

BINGHAM, E. C.—Fluidity and Plasticity. 1922.

BOYLE, ROBERT.—The Sceptical Chymist. n.d.

BROWNE, C. A.—Handbook of Sugar Analysis. 1912.

Chemical Society.—Annual Report for 1921. 1922.

CROWTHER, J. A.—Ions, Electrons and Ionizing Radiations, Ed. 2. 1922.

Engineering Index for 1921. 1922.

FUNK, CASIMIR.—The Vitamines, Ed. 2. 1922.

Hawaiian Chemists' Association.—Methods of Chemical Control for Cane Sugar Factories. 1916.

MANNING, H. P.—Fourth Dimension Simply Explained. 1921.

MOORE, E. S.—Coal. 1922.

PALMER, T. G.—Sugar Beet Seed. 1918.
RAYLEIGH, J. W. STRUTT, BARON.—Scientific Papers 1869–1919. 6 vols. 1899–1920.
ROLFE, G. W.—The Polariscope. 1919.
SURFACE, G. T.—The Story of Sugar. 1920.
ULLMANN, FRITZ.—Enzyklopädie der Technischen Chemie, vol. 10. 1922.

GIFTS.

American Institute of Electrical Engineers, Year Book 1922. New York City, New York, 1922. (From the Institute.)

American Society of Civil Engineers, Year Book for 1922. New York City, New York, 1922. (From the Secretary.)

Boston and Maine Railroad, Eighty-ninth Annual Report, for 1921. Boston, Massachusetts, 1921. (From the Directors.)

Burhorn, Edwin, Company, Cooling Towers. New York City, New York, 1922. (From the Company.)

Canadian Pacific Railway Company, Annual Report for 1921. Montreal, Canada, 1922. (From the Company.)

Chicago, Rock Island and Pacific Railway Company, Forty-second Annual Report for year ending December 31, 1921. New York City, New York, 1921. (From the Company.)

Cincinnati Milling Machine Company, Locomotive Repairs. Cincinnati, Ohio, 1921. (From the Company.)

Connecticut Public Utilities Commission, Tenth Annual Report. Hartford, Connecticut, 1922. (From the Commission.)

Connecticut State Geological and Natural History Survey, Bulletins 23 to 32. Hartford, Connecticut, 1921. (From the State Geologist.)

Danzig Technische Hochschule, Programm für das Studienjahr 1921–1922. Danzig, Germany, 1921. (From the High School.)

Denison University, Annual Catalogue 1921-1922. Granville, Ohio, 1922. (From the University.)

Disston, Henry, and Sons, The File in History and The Saw in History. Philadelphia, Pennsylvania, no date. (From the Company.)

Donnelly Systems Company, Steam Circulation and Bulletin 25 on Steam and Water Circulation. New York City, New York, 1922. (From the Company.)

Evans, R. A., Limited, Electric Lift Accessories and Parts. Leicester, England, 1921. (From the Company.)

Fellows Gear Shaper Company, A New Development in Gear Cutting. Springfield, Vermont, 1922. (From the Company.)

Goddard and Goddard Company, Pamphlet of Tools. Detroit, Michigan, 1922. (From the Company.)

Goucher College, Announcements for 1922-1923. Baltimore, Maryland, 1922. (From the College.)

Great Britain Meteorological Office, Report on Observations for the Year Ending March 31, 1921, on Atmospheric Pollution. London, England, 1922. (From the Office.)

Heine Safety Boiler Company, Steam Boiler Engineering. St. Louis, Missouri, 1920. (From the Company.)

Hoffman Manufacturing Company, Limited, Catalogue of Ball and Roller Bearings. Chelmsford, Essex, England, no date. (From the Company.)

Illinois Department of Registration and Education, State Water Survey Bulletin 17 and Index to Bulletins 1 to 16. Urbana, Illinois, 1921. (From the Department.)

Institution of Civil Engineers, Minutes of Proceedings, vol. ccxi. London, England, 1921. (From the Institution.)

Johns Hopkins University, Register, 1921-1922. Baltimore, Maryland, 1922. (From the University.)

Klein, Felix, The Mathematical Theory of the Top. New York City, New York, 1897. (From Dr. George A. Hoadley.)

Lafayette College, General Catalogue 1921-1922 and Announcements for 1922-1923. Easton, Pennsylvania, 1922. (From the College.)

Little Falls Board of Public Works, Twenty-seventh Annual Report and Thirty-fourth Annual Report of Water Commissioners. Little Falls, New York, 1921. (From the Board.)

Medways Safety Lift Company, Limited, Catalogue of Lifts and Cranes. London, England, 1922. (From the Company.)

Meldrums, Limited, Institution and Trade Refuse Destructor, Mechanial Stokers, Forced Draught Furnaces and Sack Steam Disinfector. Manchester, England, no date. (From the Company.)

Monitor Controller Company, Bulletin 101, Starting Small A C Motors. Baltimore, Maryland, 1922. (From the Company.)

Nash Engineering Company, Bulletins 10, 11, 15, 16, 17 and 18. South Norwalk, Connecticut, 1922. (From the Company.)

National Association of State Universities, Transactions and Proceedings, vol. 19. Lexington, Kentucky, 1921. (From the Association.)

National Association of Wool Manufacturers, Annual Wool Review for 1921. Boston, Massachusetts, 1922. (From the Secretary.)

New England Association of Commercial Engineers, 1922 Year Book and Business Directory. Boston, Massachusetts, 1922. (From the Association.)

New Hampshire Public Service Commission, Reports and Orders. Concord, New Hampshire, 1922. (From the Commissioners.)

New York Chamber of Commerce, Chambers of Commerce in the United States. New York City, New York, 1922. (From the Secretary.)

New York Meteorological Observatory, Report for the Year 1921. New York City, New York, 1921. (From the Observatory.)

New York, Ontario and Western Railway Company, Annual Report and Statement of Accounts for Year Ended December 31, 1921. New York City, New York, 1921. (From the Company.)

New Zealand Census and Statistics Office, Results of a Census, Part I. Population and Appendices A, B, C, D, E and F. Wellington, New Zealand, 1921. (From the Government Statistician.)

North Dakota Society of Engineers, Proceedings of the Twelfth and Thirteenth Annual Meetings. University, North Dakota, 1921. (From the Secretary.)

Northampton Water Commissioners, Fifty-first Annual Report. Northampton, Massachusetts, 1921. (From the Commissioners.)

Payne Dean, Limited, Bulletins 43-A, 55-P, 100-A and 200-S. New York City, New York, 1922. (From the Company.)

Paint Manufacturers' Association of the United States, Fineness and Bulk of Pigments by Henry A. Gardner. Washington, District of Columbia, 1922. (From the Association.)

Pennsylvania Bureau of Topographic and Geological Survey, Bulletins 10, 11, 13, 17, 21, 26, 27, 28, 32, 33, 34 and 35. Harrisburg, Pennsylvania, 1922. (From the State Geologist.)

Pennsylvania System, Record of Transportation Lines. Philadelphia, Pennsylvania, 1922. (From the Chief Engineer.)

Piggott, Thomas, and Company, Booklets of Pipes and Photographs. Birmingham, England, 1910 and 1914. (From the Company.)

Power Plant Company, Limited, Turbine Gears. West Drayton, England, 1921. (From the Company.)

Quigley Furnace Specialties Company, Inc., Hytempite in the Power Plant. New York City, New York, 1921. (From the Company.)

Ransom, A., and Company, Limited, Horizontal Log Band Saws. Newark-on-Trent, England, 1922. (From the Company.)

Ridgway Dynamo and Engine Company, Bulletin No. 30. Ridgway, Pennsylvania, 1921. (From the Company.)

Saint Louis Machine Tool Company, Catalogue No. 16. Saint Louis, Missouri, 1920. (From the Company.)

Sangamo Electric Company, Sangamo Meters, Bulletins Nos. 58 and 59 Springfield, Illinois, 1921. (From the Company.)

Sarco Company, Incorporated, Booklet of Sarco Temperature Control. New York City, New York, 1922. (From the Company.)

Schade Valve Manufacturing Company, Catalogue 3-A of Steam Specialties. Philadelphia, Pennsylvania, 1922. (From the Company.)

Sebastian Lathe Company, Catalogue No. 26 of Sebastian Lathes. Cincinnati, Ohio, no date. (From the Company.)

Smith and Serrell, Bulletins 32 and 34, of Flexible Couplings. Newark, New Jersey, 1921. (From the Company.)

Society of Engineers, Transactions for 1921. London, England, 1921. (From the Society.)

Standard Scientific Company, Electrical Accessories for Laboratory and Commercial Use. New York City, New York, 1921. (From the Company.)

Stevens Institute of Technology, Annual Catalogue 1922–1923. Hoboken, New Jersey, 1922. (From the Institute.)

St. Louis University, Bulletin 6 of Volume 17. St. Louis, Missouri, 1922. (From the University.)

St. Louis Mercantile Library Association, Seventy-sixth Annual Report. St. Louis, Missouri, 1922. (From the Association.)

Sturtevant, B. F., Company, Bulletin 246, Generator Cooling Apparatus. Boston, Massachusetts, 1921. (From the Company.)

Sturtevant, B. F., Company, Bulletin 290, Silentvane Fan. Hyde Park, Boston, Massachusetts, 1922. (From the Company.)

Sturtevant Mill Company, The Modern Fertilizer Plant. Boston, Massachusetts, 1921. (From the Company.)

Syracuse Bureau of Water, Annual Reports for 1919, 1920 and 1921. Syracuse, New York, 1922. (From the Bureau.)

Tennessee State Geological Survey, Bulletins 25 and 26. Nashville, Tennessee, 1921. (From the State Geologist.)

Tide Water Oil Sales Corporation, Industrial Oils. New York City, New York, 1920. (From the Corporation.)

Track Specialties Company, 1922 Booklet of Trasco Devices. New York City, New York, 1922. (From the Company.)

Traveling Engineers' Association, Proceedings of the Twenty-ninth Annual Meeting. Cleveland, Ohio, 1921. (From the Secretary.)

Treadwell Engineering Company, "Stoever" Pipe Machines. Easton, Pennsylvania, 1922. (From the Company.)

Trenton Department of Conservation and Development, Annual Report for Year Ending June 30, 1921. Trenton, New Jersey, 1921. (From the Department.)

Union Malleable Iron Company, Catalogue 10 of Chains. East Moline, Illinois, 1921. (From the Company.)

United States Geological Survey, Bulletin 735B, Colemanite in Clark County, Nevada, and Cobalt, Molybdenum, Nickel, and Vanadium in 1920. Washington, District of Columbia, 1922. (From the Survey.)

University of Cincinnati, Publications of the Cincinnati Observatory, No. 19. Cincinnati, Ohio, 1922. (From the University.)

University of Denver, Fifty-ninth Year Book, Register for Academic Year 1921-22 and Announcements for 1922-1923. Denver, Colorado, 1922. (From the University.)

University of Illinois, Annual Register 1921-1922. Urbana, Illinois, 1922. (From the University.)

University of Maine, Annual Report for the Year Ended June 30, 1921. Orono, Maine, 1921. (From the University.)

University of Nebraska, Annual Catalogue of the College of Engineering, and Announcements 1922-1923. Lincoln, Nebraska, 1922. (From the University.)

University of North Carolina, North Carolina Club Year-Book, 1920-1921. Chapel Hill, North Carolina, 1921. (From the University.)

University of Toronto Engineering Society, Transactions and Year Book. Toronto, Canada, 1922. (From the Society.)

Wagner Electric Manufacturing Company, Bulletin 129. St. Louis, Missouri, 1922. (From the Company.)

Wells, Henry, Oil Company, "Germ Process" Motoils. London, England, no date. (From the Company.)

Wickes Boiler Company, Bulletin 7. Saginaw, Michigan, no date. (From the Company.)

BOOK NOTICES.

Organic Chemistry, or Chemistry of the Carbon Compounds. By Victor von Richter. Edited by R. Anschütz and H. Meerwein, vol. ii, Chemistry of Carbocyclic Compounds. Translated from the Eleventh German Edition, by E. E. Fournier D'Albe, D.Sc., A.R.C.Sc. xvi-728 pages and index, 8vo. P. Blakiston's Son and Company, Philadelphia. Price $8.00 net.

Richter's chemistry in English form has been so long before the American public, and has been received with so much favor that but little opportunity is afforded to say anything new about it. The present translation is by a resident of England, and is certainly a work of immense detail and a thorough presentation of the multiplicities of combination of which the cyclic compounds are capable. The present edition embodies the same general character as the former ones, but is much extended and the mind is likely to become dazed by looking over the lists of derivatives from even the simplest of the molecules. The progress of this department of chemistry has brought out the structural formulas of many natural products, such as glucosides, colors and proteins which formerly were known only by their percentage composition, and for which purely arbitrary names had to be devised. Thus, the formula of amygdalin, the glucoside of many plants of the rose family, is given, showing it to be mandelo-nitrile diglucose.

The work maintains its standard as a very comprehensive enumeration of the data of organic chemistry. The present edition is well printed on good paper.

Henry Leffmann.

The Chemistry of the Non-benzenoid Hydrocarbons and Their Simple Derivatives. By Benjamin T. Brooks, Ph.D. 612 pages, including index, 8vo. The Chemical Catalog Company, New York, 1922. Price $7.00 net.

As Doctor Brooks remarks in the preface to this work, the attractive and facile chemistry of benzene and its related substances has diverted attention from other hydrocarbon groups. He suggests that this diverting affects unfavorably the compilation of text-books, in so far as the student is not given a proper picture of the close relationships and similarity of chemical behavior of the non-benzenoid groups. A reference is made to Wells' "Outline of History," but the reviewer is compelled to express a doubt whether that writer, though highly distinguished in general literature, is sufficiently acquainted with science to be able to give advice as to its methods or warn of its errors.

The book, of course, includes many cyclic compounds, large space being given to the terpene group. Doctor Brooks points out that while a large amount of work has been done in perfecting the engineering of petroleum, the urge in this direction has been mainly the profit derived therefrom, while a study of the purely chemical phases of the question has been comparatively neglected. Such studies will surely result in practical advantages, but after all, the research must be undertaken for the sake of ascertaining the truth whether such truth can be "made to pay" or not. "A great deal of painstaking systematic research in the field of the non-benzenoid hydrocarbons must be carried out, which may never be utilized in an industrial process." This sentence expresses the true purpose of science, which is the discovery of truth. The commercial value of the discovery must be regarded as merely incidental. In no phase

of chemistry is this fact better shown than in the work done in Germany in the study of the benzenoid groups, work largely carried out as pure science, but afterwards resulting in great industrial applications. It is, of course, true that after the initial discoveries had indicated valuable results, German chemists were principally directed to the practical lines, but at no time were the interests of pure science neglected. Many years ago, a German chemist said that it was due to the coöperation of theory and practice that the coal-tar industry of Germany had conquered the world, and, though at that time, many might have questioned the accuracy of the statement as to the conquest, the events of the war showed what had been accomplished.

Doctor Brooks emphasizes the need of intensive research in the field to which his book is devoted, pointing out the needs of petroleum, rubber, turpentine and essential oil industries for systematic theoretical information. American chemists have not been conspicuous in this line, as an enumeration of the leading authorities in it will show, for in such a list which is given, American names are noted by their absence. The book in hand is directed to presenting the ascertained data concerning the benzenoid hydrocarbons and to showing the close relationships which exist between many of them.

As an illustration of the value of theoretical discussion, the presentation of the theories of the double linking in the unsaturated olefines will serve well. The chemical behavior and physical properties of such molecules are fully as important as those of the true benzene type. Much attention is given in this chapter to the modifications of structure to which these ethylene groups are liable, and to the cyclic arrangements that they developed. That the group $>C=C<$ is unstable, or under stress, is indicated by a wealth of experimental evidence. The labors of Lewis and Langmuir in the study of atomic arrangements have been of value in explaining the theories of carbon linkings. The details of these applications are given considerable space, forty-six pages, elaborately illustrated by open chain and cyclic formulas, being devoted to the study of the "ethylene bond."

The book is divided into seventeen chapters, covering the field of the non-benzenoids and presenting in great detail the characters of the raw materials, the winning and nature of the crudes, preparation of the derivatives and properties thereof and the commercial and industrial relationships. An interesting series of data is that relating to the oxidation of the paraffines to fatty acids by direct oxidation, with or without the assistance of a catalyst. The shortage of fats in Germany during the war led to an active research as to the possibility of producing fatty acids from these hydrocarbons, in which a special commission was engaged under the direction of Engler. The data given out are, however, as is the case with much of the result of German war studies in chemical fields, somewhat scanty and contradictory, but it seems the best results have been obtained without a catalyst except a small amount of previously oxidized material as an initiator.

The descriptions are not limited to mere enumeration of the properties of the substances, but much space is given to supply and specific uses. Thus, the camphor outlook, both as to the natural and synthetic products, is given several pages, and in connection with petroleum the physical chemistry of lubricating oils is set forth.

The book is crowded with information on topics that are but scantily treated in ordinary text-books, and even in special works, and is a most valuable addition to the literature of hydrocarbon chemistry. The printing and illustrating (the latter principally structural formulas) are of the best quality, and the book is another one of those of recent appearance of which Americans may be proud, being one of the many indications that

"Westward the star of (chemical) empire takes its way."

HENRY LEFFMANN.

MESSUNG GROSSER GASMENGEN. Anleitung zur praktischen Ermittlung grosser Mengen von Gas-und Luftströmen in technischen Betrieben. By L. Litinsky, Chief Engineer, Leipzig. xv-266 pages, index, 138 illustrations, numerous tables, diagrams and a chart of comparative data concerning 18 methods of measurement, 8vo. Leipzig, Otto Spamer, 1922. Paper bound, 525 marks.

"Fuel economy is the slogan of the day." With this true and appropriate remark, the author of the book in hand begins his preface. With all classes of fuel, whether coal or oil as such, or the gaseous products therefrom, systems of economy are indispensable. An important step towards this is the correct measurement of the amounts used in industrial operations. The measurement of solid or liquid materials, horsepower, electric output may be regarded as solved problems, but gaseous fuels offer much greater difficulty. It is, however, a very important problem, and has been studied with great care. Much ingenuity has been shown in the construction of apparatus for measuring the large volume of gases employed or distributed by some of the great industries. The problems do not merely concern combustible gases; compressed air, sulphur dioxide, ammonia and chlorine are now prepared on the large scale, and an economy in regard to these is indirectly an economy of fuel, for, in the great majority of cases, industries have to consider the coal-pile. Progress in the application of exact measuring methods to gases has been somewhat retarded by the belief that they can be carried out only with great difficulty, whereas we are assured that there are now available simple and efficient apparatus for all purposes, apparatus that may replace the ordinary gas-meter, where that is not suitable. The great differences in the nature of gases render the problem, of course, more complicated than with solid or liquid materials. Gases respond so readily to differences of temperature and pressure, are so liable to contain impurities not evident to ordinary inspection, and possess such differences in their action on materials of construction, as witness the contrast between sulphur dioxide and ammonia, that many modifications must be made in the general type in order to adapt the apparatus to requirements of industries. The author has sifted the literature with great care, and has incorporated in the book an extensive bibliography, in which it is somewhat depressing to note the rarity of quotations from American sources. Whether this is due to the interruption of the opportunities to consult American books and journals during the past few years, or because the Americans have written but sparingly on the subject, cannot be determined here.

The author complains that in many establishments, even those recently equipped, no proper apparatus for gas measurement is installed. The work

Roche, who said in the Irish Parliament "Why do anything for posterity? What has posterity done for us?" Doctor Jillson, indeed, appropriately terms the present time "The Age of Waste." That many sources of raw materials are now approaching exhaustion is the opinion of those who have studied the subject, and natural gas is one that is perhaps nearest to this condition. In 1917 the peak production so far noted occurred, the output reaching over three-quarters of a billion cubic feet. Since then the production has been less and less each year. Oil reserves are also being seriously impoverished. The work in hand relates especially to the Kentucky natural gas supply and production, but the data are of value to all interested in the problem. The book is illustrated with a number of photogravures, representing actual conditions of avoidable waste in collection, transportation and distribution, and deserves wide circulation as a contribution to the cause of fuel economy. It is a neatly printed and well-written monograph.

<div align="right">HENRY LEFFMANN.</div>

PENROSE'S ANNUAL. Volume 24 of the Process Year-Book and Review of the Graphic Arts. Edited by William Gamble, F.R.P.S., F.O.S. 64 pages, with many illustrations in color and plain, quarto form. Lund, Humphreys and Company, Limited, London, 1922. Price $4.00.

The merits of this book make it difficult for the reviewer to determine upon which to expend the most praise. It is a wonderful expression of high degree of excellence to which photography and its applications, engraving and printing have been carried. Illustrated with a great variety of plates and drawings, and containing much information as to the latest developments in photographic procedures, it takes place as the most valuable and interesting of our annuals. As might be expected, several firms are concerned in the production of the work, and their identity is set forth in detail, the paper from one source, the ink from another and so on. Among the most interesting novelties in procedure is the article by C. J. Killen on tests of acid restrainers for wet-plate development. The old iron-acetic mixture became somewhat scarce during the war on account of the official curtailment on the procuring of the acid. Mr. Killen found that nitric and sulphuric acids could be substituted without objection. He gives results with different proportions of these acids, the tests showing that both have a stronger preservative effect on the iron solution than acetic acid. The value of the method was amply demonstrated by practical trials in development, and for more than a year, nitric acid was used exclusively in the establishment.

A very vivid photogravure is that of the burial of the "unknown soldier" in Westminster Abbey. The book is agreeably free from the nudes, now so common in collections of photography, and by the irony of fate, the most striking group of this type, a photogravure of the "Three Fates" in the Gallery of Fine Arts at Brussels, is faced by the staid, spectacled portrait of the Principal of Saint Bride!

The opening chapter is a review of progress in process work, incidental to which a brief sketch is given of the advances made during the last quarter century. Allusion is made to death of Mr. Friese Greene, whose name is

connected with some of the most ingenious and important inventions in photography. He is generally credited by British writers as the initiator of motion picture methods, but French writers have recently grown quite irritated on this question, asserting strongly that practical procedures in this field are wholly due to men of their own country. It is difficult to decide the question, for as usual, the development of the motion picture industry has been the work of many minds, and it may be said that there is glory enough for all.

To the photographer, engraver and professional artist the book will be a valuable companion, and to the general public a revelation of what can be accomplished in the graphic arts.

Henry Leffmann.

United States Life Tables, 1890, 1901, 1910 and 1901–1910. Prepared by James W. Glover, Expert Special Agent of the Bureau of Census. 476 pages and index, 4to. Government Printing Office, Washington, District of Columbia, 1921.

This extended and elaborated study of mortality statistics is one of benefits of the establishment of the census bureau as a permanent department of the government, instead of the older plan of gathering a miscellaneous set of officials every ten years. Mortality statistics are not matters of popular reading, but are of great importance in the study of hygiene and sociology. Unfortunately, the whole United States has not yet been brought under national control, and the collection of data is not carried out in a uniform manner. The present tables relate merely to mortality, and do not enter into the questions of the cause of death, upon which there may be much difference of opinion. It is stated in the preface that the figures show that from 1890 to 1910, mortality conditions have greatly improved for persons under 50, but have remained about stationary for those above that age. They also show great differences in the rates of mortality in different classes to the population, being much more favorable for women than for men, for persons residing in the country than for those in the city, for whites than for negroes, for native born than for foreign born. The favorable results for ages under 50 are probably largely due to the child-saving work of recent years. Interesting data are furnished as to mathematical methods of dealing with the figures and of the apparatus now applied for facilitating calculation.

Henry Leffmann.

National Advisory Committee for Aeronautics. Report No. 133. The Tail Plane. By Max M. Munk. 37 pages, illustrations, quarto. Washington, Committee, 1922.

This report deals with the calculation of the tail plane. The author has tried to simplify the present theory of longitudinal stability for that particular purpose so as to obtain one definite coefficient characteristic of the effect of the tail plane.

This coefficient is obtained by substituting certain aerodynamic characteristics and some dimensions of the airplane in a comparatively simple mathematical expression. Care has been taken to confine all aerodynamical information

necessary for the calculation of the coefficient to the well-known curves representing the qualities of the wing section. This is done by making use of the recent results of modern aerodynamics. All formulas and relations necessary for the calculation are contained in the paper. They give sometimes only an approximation of the real values. An example of calculation is added in order to illustrate the applications of the method.

The coefficient indicates not only whether the effect of the tail plane is great enough, but also whether it is not too great. It appears that the designer has to avoid a certain critical length of the fuselage, which inevitably gives rise to periodical oscillations of the airplane. The discussion also shows the way and in what direction to carry out experimental work.

Report No. 137, Point Drag and Total Drag of Navy Struts No. 1 Modified. By A. F. Zahm, R. H. Smith and G. C. Hill. 15 pages, illustrations, quarto. Washington, Government Printing Office, 1922.

In this report are recorded the results of tests on struts conducted at the Washington Navy Yard. Two models of the modified Navy strut, No. 1, were tested in the 8 by 8 foot wind tunnel. The tests were made to determine the total resistance, and effect, and the pressure distribution at various wind tunnel speeds with the length of the strut transverse to the current. Only the measurements made at zero pitch and yaw are given in this report.

Report No. 140, Lift and Drag Effects of Wing-tip Rake. By A. F. Zahm, R. M. Bear and G. C. Hill. 9 pages, illustrations, quarto. Washington, Government Printing Office, 1922.

This pamphlet describes the tests carried out at the Washington Navy Yard on models of the RAF-6, Albatross, and Sloane aerofoils to determine the effectiveness of the conventional wing-tip rake in improving aerofoil characteristics. Two degrees of rake were tested on each model; the trailing edge being always longer than the leading edge. The results are compared with the values computed by standard formulæ in use at the time the tests were conducted.

Report No. 142, General Theory of Thin Wing Sections. By Max M. Munk. 19 pages, illustrations, quarto. Washington, Government Printing Office, 1922.

This report deals with a new, simple method of calculating the air forces to which thin wings are subjected at small angles of attack, if their curvature is not too great. Two simple integrals are the result. They contain only the coördinates of the wing section. The first integral gives the angle of attack at which the lift of the wing is zero, the second integral gives the moment experienced by the wing when the angle is zero. The two constants thus obtained are sufficient to determine the lift and moment for any other angle of attack. This refers primarily to a two-dimensional flow in a non-viscous fluid. However, in combination with the theory of the aerodynamical induction, and with our empirical knowledge of the drag due to friction, the results are valuable for actual wings also. A particular result obtained is the calculation of the elevator effect.

PUBLICATIONS RECEIVED.

Penrose's Annual, volume xxiv of the Process Year-book and Review of the Graphic Arts. Edited by William Gamble, F.R.P.S., F.O.S., 1922. 91 pages, illustrations, colored plates, quarto. New York, Tennant and Ward, 1922. Price, $4.00.

The Chemistry of the Non-benzenoid Hydrocarbons and Their Simple Derivatives, by Benjamin T. Brooks, Ph.D. 612 pages, illustrations, 8vo. New York, The Chemical Catalog Company, 1922. Price, $7.00 net.

History of the Telephone and Telegraph in Brazil, 1851–1921, by Victor M. Berthold, Chief Foreign Statistician, American Telephone and Telegraph Company. 92 pages, 8vo. New York City, New York, 1922.

Chemische Technologie in Einzeldarstellungen, Herausgeber, Prof. Dr. A. Binz. Allgemeine Chemische Technologie. Messung grosser Gasmengen. Anleitung zur praktischen Ermittlung grosser Mengen von Gas—und Luftströmen in technischen Betrieben von L. Litinsky. 274 pages, illustrations, plates, 8vo. Leipzig, Otto Spamer, 1922. Price, paper, 525 marks.

Department of Commerce, Bureau of the Census: United States Life Tables 1890, 1901, 1910, and 1901–1910. Explanatory text, mathematical theory, computations, graphs, and original statistics, also tables of United States life annuities, life tables of foreign countries, mortality tables of life insurance companies. Prepared by James W. Glover, expert special agent of the Bureau of the Census. 496 pages, illustrations, diagrams, quarto. Washington, Government Printing Office, 1921.

Engineers' Club of Philadelphia: Report of the Sesqui-Centennial Committee on Sites. To the President and the Executive Committee of the Sesqui-Centennial Exhibition Association. 42 pages, plates, maps, oblong 8vo. Philadelphia, 1922.

Ontario Department of Mines: Thirtieth annual report. Ontario Gold Deposits, Their Character, Distribution and Productiveness, by Percy E. Hopkins. 73 pages, illustrations, maps, 8vo. Toronto, King's Printer, 1922.

U. S. Bureau of Mines: Bulletin 200. Evaporation Loss of Petroleum in the Mid-continent Field, by J. H. Wiggins. 115 pages, illustrations, plates, 8vo. Technical Paper 268. Preparation and Uses of Tar and its Simple Crude Derivatives, by W. W. Odell. 84 pages, illustrations, plates, 8vo. Washington, Government Printing Office, 1922.

National Advisory Committee for Aeronautics: Technical Notes No. 90, Sylphon Diaphragms. A method for predicting their performance for purposes of instrument design, by H. N. Eaton and G. H. Keulegan, Bureau of Standards. 14 pages, illustrations, quarto. No. 94. Notes on Propeller Design II: The Distribution of Thrust Over a Propeller Blade, by Max M. Munk. 9 pages, quarto. No. 95, Notes on Propeller Design III: The Aerodynamical Equations of the Propeller Blade Elements, by Max M. Munk. 10 pages, illustrations, quarto. No. 97, N.A.C.A., Control Position Recorder, by F. N. Norton, Langley Memorial Aeronautical Laboratory. 3 pages, photographs, quarto. Washington, Committee, 1922.

CURRENT TOPICS.

The Camphor Outlook.—The recently published work of Brooks on the " Non-benzenoid Hydrocarbons " devotes considerable space to the camphor problem, in relation to the practicability of the synthetic product competing with the natural. The large tree, *Cinnamomum camphora*, is the only source of the natural article and the process of distilling with steam the chipped wood of mature trees has been carried out in China and Japan for several centuries. Japan has acquired control of practically all of the region occupied by these trees, and the price of camphor has been deliberately advanced, which gave occasion to earnest efforts to produce it artificially. The greatly increased use of camphor, owing to the development of the manufacture of celluloid, still further much increased by the demand for photographic film, has added to the importance of this supply, as has also the demand for transparent windows for automobiles.

For the production of synthetic camphor, the successful methods employ turpentine or pinene as raw material, and unfortunately while the primeval camphor forests of Asia are being rapidly reduced, the American turpentine trees are also disappearing. Doctor Brooks expresses the hope that the substitution of light petroleum products in the paint and varnish industries will conserve much of the supply of turpentine. Efforts have been made to cultivate camphor trees, but the substance does not exude from the tree as does turpentine. The woody material must be distilled with steam. The distillation of leaves has not proved profitable. Considerable planting of camphor as trees has been done in Florida and California, as well as in some parts of the East Indies. Synthetic camphor is prepared from turpentine by conversion into bornyl chloride, the principal source of which is the long-leaved pine, *P. palustris*. The turpentine should be fresh, as old turpentine gives a low yield of bornyl chloride. Borneol, from which bornyl chloride is prepared, exists in Borneo camphor, but the supply from this source is not sufficient.

In this connection, however, a timely suggestion for increasing the yield of turpentine is presented in a paper by W. H. Mason, Laurel, Mississippi, which was read before the Southern Pine Association, and abstracted in *Building* (Philadelphia). Mason has carried out on a large scale, and with much success, two processes for extracting turpentine, pine oil and rosin from sawed lumber. In one process the drying is conducted mainly as in the ordinary dry-kiln method, but in the first 24 hours steam is used instead of air, and the vapors are led to a condenser. The condensed liquid consists of water and turpentine, which are separated. It is found that the lumber is dried better and more thoroughly, with less warping and will hold paint better. The process has been in use for more than a year.

The yield on long leaf pine is about one gallon of turpentine per 1000 feet; on short leaf pine about half this.

In the second method called "pitch extraction," only the pitch is treated. A grading expert marks the "fat" pieces, which are run into a special retort with steam coils in the bottom. Turpentine is run in and boiled up by which the pitch is extracted and water driven out. The solvent liquor is sent to the refining plant to recover the constituents. H. L.

The Adsorption of Gas Under Pressure. H. Briggs and W. Cooper. (*Proc. Royal Soc.*, Edinburgh, Vol. xli, Part II.)—Adsorbing material, such as charcoal, silica or coal, was dried and then used to fill a small steel cylinder. Dry gas was then compressed into the cylinder. The gas was later allowed to flow out through a meter, readings of pressure being taken from time to time. The cylinder was kept in a water-bath.

Activated cocoanut charcoal exhibited the greatest adsorption under pressure. A litre filled with this substance will hold at a pressure of 20 atmospheres 50 litres of nitrogen measured at normal pressure and at 15° C., or 36 litres of hydrogen, whereas in the absence of the charcoal it would hold only 20 litres of either gas on the supposition that Boyle's Law holds. "The gas-capacity of a cylinder intended to hold nitrogen under compression may be increased by filling the cylinder with dry cocoanut charcoal. The advantage gained by the charcoal is especially marked for pressures below 50 atmospheres. When blown off from 35 atmospheres, abs. to 1 atmosphere abs., for example, a cylinder containing cocoanut charcoal would discharge 66 per cent. more nitrogen than the same cylinder containing no adsorbent. Put in another way, the results indicate that a cylinder of 1 cubic foot water capacity filled with dry cocoanut charcoal and charged with nitrogen at 21 atmospheres would hold a total volume of 50 cubic feet of gas, of which 43.5 cubic feet would be discharged on the pressure being released to atmospheric. Had the cylinder not held charcoal it would require to have been charged to 44.5 atmospheres abs. to yield the same volume."

In several cases examined there is no such advantage obtained by the use of an adsorbent, but coal associated with outbursts of firedamp acted in the same way as the charcoal above. "By taking some anthracite ejected at an outburst in South Wales, drying it, and filling it into a gas-cylinder, and pumping in pit firedamp, it was found that one cubic foot of the coal was able to take up at 6 to 8 atmospheres pressure, and hold in a condition ready for almost instantaneous release, a quantity of firedamp considerably greater than could be contained in one cubic foot of open space charged with gas at the same pressure. The sudden outburst of gas constitutes, in fact, a problem in gaseous adsorption; the gas is held in the coal in a state available for discharge when the pressure is released."

G. F. S.

Pasteur Centennial.—Commemoration of the centennial anniversary of the birth of Pasteur will be the occasion of the erection of a statue facing the Strasbourg University, where as a professor, he began his career. The inauguration ceremonies will take place on May 1, 1923, under the patronage of the Republic, and will consist principally in the unveiling of the statue and the opening of an exhibition of Hygiene and Bacteriology. This exhibition will be mainly arranged to show the advances made in these subjects as a result of Pasteur's work. A Congress of Hygiene and Bacteriology will be held at the same time.

In estimating the work of Pasteur, his earlier investigations into the phenomena of racemism must not be forgotten. His later work in the study of pathogenetic organisms has overshadowed to a certain extent his labors in physical science, but these were epoch-making. His investigations extended over many years, the results appearing from time to time in French journals, with more or less extended abstracts in the journals of other countries, but in the early part of 1860 he delivered, by request, before the Paris Chemical Society, two lectures in which he summarized his labors, and set forth the interesting and highly important method of " mesotomization," that is, breaking up the racemic association so as to secure one of the active constituents. He also called attention to the curious asymmetry of the crystals of some of these compounds. His experiments were conducted on the tartrates. The two lectures have been printed in English as No. 14 of the " Alembic Club Reprints," with the title, " Researches on the Molecular Asymmetry of Natural Organic Products." A translation into German has appeared as No. 28 of Ostwald's " Klassiker der exacten Wissenschaften."

It is to be hoped that the orators to whom will fall the lot to deliver the addresses on the occasion of the dedication of the statue will not fail to lay some stress on the service which these early researches rendered to organic chemistry.   H. L.

The American Philosophical Society, at its annual meeting on April 22nd, awarded the Magellanic Premium, established in 1786 by a friend of Benamin Franklin, to Paul R. Heyl and Lyman J. Briggs, conjointly, for the invention of the Earth Inductor Compass. It will be recalled that Doctor Heyl was the recipient some years ago of a part of the Boyden Premium from The Franklin Institute, for his investigation of the light from Algol with a view to solving the question raised by the donor " whether all rays of light, and other physical rays are or are not transmitted with the same velocity."

The close of the war left the air pilot without a compass that would function well under the adverse conditions of high speed, great acceleration, and sharp turns of direction prevailing in the aeroplane. The Bureau of Standards, therefore, at the request of the U. S. Air Service undertook the very practical problem of devising an adequate compass. As a result the two medallists have produced a

compass that consists essentially of a dynamo whose field is the magnetic field of the earth. The armature, consisting of four teeth or spokes of iron wrapped with coils and rotating in a horizontal plane, is driven with an angular velocity of 20 revolutions per second by an anemometer at the top of the vertical axis. Two pairs of brushes carry off the two direct currents to an apparatus in which the position of an index needle is determined by the currents. The arrangement is such that this needle stands at zero provided the airplane is on its prescribed course. A deviation from the course causes a corresponding departure of the needle from zero.

There are four special features in the compass—

1. The null method of setting the course.

2. The employment of iron in the armature, in contradistinction to the usual practice in earth inductors. Silicon iron is used which, very fortunately, has a high permeability for fields as strong as that of the earth and also a small retentivity. The use of the iron renders a smaller inductor possible, thus compensating for the additional weight due to the iron. The whole apparatus was not to exceed 25 pounds in weight. The finished compass actually weighs almost exactly one-half of this specified amount.

3. Distant control of the indicating apparatus. The dynamo is mounted in the back part of the fuselage, where it is out of the way and where, furthermore, there is the least motion.

4. A special arrangement to keep the axis of the dynamo vertical. In fact the armature swings on a short, heavy, damped pendulum. After a sharp turn it returns to verticality in a short time and in a dead-beat manner. The compass has stood the practical test of repeated flights and works well in all cases except in a few very special " stunt " evolutions. G. F. S.

Blast-furnace Slag for Roads. (*U. S. Department of Agriculture, Press Service Sheet No. 199.*)—Blast-furnace slag as a material for concrete road construction is to be thoroughly studied by the Bureau of Public Roads. With the enormous demand for road-building material, officials say, economy demands the use of material close at hand wherever possible, and the Bureau is now conducting investigations of different materials with this in view.

Great quantities of slag are to be found at blast furnaces in various parts of the country. Samples from 32 plants have been collected and will be made into concrete and tested for resistance to wear, strength, water absorption, and general utility. These results will be compared with similar tests made on other materials.

In addition to the laboratory tests it is possible that the experiments will be followed by an inspection of a number of concrete roads built with slag as the coarse material. These roads will be selected in various parts of the country and the reports, together with the laboratory tests, will furnish information which can be fully relied upon.

Platinum Conditions.—The enormous advance in the price of this metal in late years has proved very embarrassing to chemists and to several industries. This advance has unfortunately contributed to additional difficulty because it has diverted the metal to a use for which it is really not adapted, namely, jewelry. There is no reason to doubt that the practice of setting precious stones in platinum has been adopted because of the high cost of the material, for it has a poor lustre and does not set off the stone as well as gold. George F. Kunz has recently reviewed the conditions of the platinum supply and uses, and some of the data that he sets forth are here noted, being taken from recent issues of the *Chemical News*. The industry is gradually emerging from the chaotic condition into which it was plunged by the war, and even the Russian sources are beginning to be active. A notable increase of production is also recorded in Colombia, the locality, by the way, in which the metal was first detected. The Colombia mines were actively exploited while the Russian mines were blocked, but American companies are now endeavoring to stabilize the South American sources. The price of the metal has fallen somewhat, though still very high. An increased demand for jewelry and dental work has arisen since the close of the war which tends to keep up the price. In 1920 the consumption of platinum in the United States was 141,041 troy ounces, of which 57 per cent. was taken by jewelers, 19 per cent. by electrical industries, 11 per cent. by dental industries, 10 per cent. by chemical operations, the remainder being distributed in minor lines.

Naturally active search has been made for new platinum deposits, but so far no great rewards have come. Kunz states that the outlook for some Alaska exploitations is rather encouraging. In Colombia, the principal deposits are in the Atrato and San Juan Rivers, but a third river is regarded as likely to yield a supply. The United States is about to pay Colombia a large sum as indemnity, and it is hoped that much of this will be used to develop some of the Colombia industries, especially the platinum deposits. Undoubtedly a marked fall in the cost of platinum will be a great advantage to chemists.

H. L.

Application of the Electron Theory of Chemistry to Solids. SIR J. J. THOMSON. (*Phil. Mag.*, April, 1922.)—"Each kind of atom has associated with it a definite number of electrons which form its outer layer when it is in the free state: it is by the rearrangement of these electrons that it is able to hold other atoms, whether of the same or different kinds, in chemical combination. When these atoms aggregate and form a solid there will be in each unit volume of the solid a definite number of these electrons, and the problem is to distribute the electrons so that they will form with the atoms a system in stable equilibrium. . . . We shall begin with the simplest case when the atoms are all of the same kind, *i.e.*, when the solid contains only one chemical element. We suppose that the electrons

are arranged as a series of cells which fill space and that each cell surrounds an atom; the number of cells is equal to the number of atoms. If the atom is monovalent the number of electrons is equal to the number of atoms, if divalent to twice that number, if trivalent to thrice that number and so on. This condition will determine the shape of the cell. If the cells have to be similar and equal and to fill up space without leaving gaps, they must be of a limited number of types. These are as follows: (1) Parallelepipeda, if the atoms are of the same kind these may be expected to be cubes; (2) hexagonal prisms; (3) rhombic dodecahedra; (4) cubo-octahedra."

Let one illustration suffice for the type of reasoning employed. Suppose space to be filled with cells of cubical form packed one against the other, and at each of the eight corners of each cube let there be an electron, and, in addition, let there be an electron at the middle of each of the twelve edges of the cube. First, we consider the corner electrons alone. At each corner eight cubes meet and one electron is there, one-eighth of an electron to the account of each cube. The same holds for each of the eight corners of each cube. To the cube's account we therefore reckon eight times one-eighth or one entire electron. Now for the edge electrons. Only four cubes come together at this edge, so the electron at the middle of this common edge is divided equally between the four cubes. The cube has twelve edges, so to its account from the edges there are twelve times one-fourth or three electrons. One electron from the corners and three from the middles of the edges make a total of four for each cube, a possible arrangement for a tetravalant element, which turns out to be less stable than another arrangement. "For most of the valencies more than one arrangement of the electrons is possible, indicating that for such elements there might be allotropic modifications with different crystalline forms." The author next examines on dynamic grounds the stability of certain of the possible configurations of the electrons. This leads to a calculation of the maximum frequency of the vibrations of the electrons and some very satisfactory agreements between the outcome of theory and the data of experiment are noted. Similar agreements are further found in the cases of the bulk modulus and of the dielectric constant.

This paper marks a notable advance toward the complete understanding of crystals. G. F. S.

Decomposition of Ammonium Nitrate.—Interest in this subject has been developed of late owing to the great explosion at Oppau, the cause of which has not been determined, or if determined by the German experts, has not been definitely published. Suggestions have been made that it was in part due to ammonium compounds. The formula of ammonium nitrate indicates that it may be an explosive if the proper initiative is applied. At a moderate temperature it decomposes almost wholly into water and nitrous oxide, a procedure that has been used for many years on a very large scale for the manu-

facture of the well-known anæsthetic. It has been noticed, however, that irregular reactions often take place, especially the formation of small amounts of nitric oxide, and for commercial purposes the gas is always carefully purified. H. L. Saunders (*Jour. Chem. Soc.*, April, 1922, 698) gives the results of careful studies of the decomposition of the salt, finding that over a range of from 210° to 260° C. the course of decomposition is unaltered, about 98 per cent. of the salt decomposing into nitrous oxide and water, but a small amount of free nitrogen is always present. At a temperature of 300° the decomposition occurs explosively, and large amounts of nitrogen are set free. The reactions under the explosive decomposition are quite different from those which occur at the lower temperatures (quiet decomposition), producing nitric oxide, nitrogen peroxide and nitrogen in the ratio $2:4:5$. Chlorides, which are often present in commercial samples, influence very unfavorably the action, free chlorine being almost always found in the gas. The higher the initial temperature of decomposition, the lower the proportion of nitrous oxide. A certain amount of liquid is produced which always contains nitric acid, and also hydrochloric when chlorides are present in the salt used. Sulphates are without special influence, and small amounts of sodium nitrate—a not infrequent impurity of the commercial salt— do not influence the decomposition below 250°.　　　H. L.

Note on a Possible Relationship between the Focal Length of Microscope Objectives, and the Number of Fringes Seen in Convergent Polarized Light. F. I. G. RAWLINS. (*Phil. Mag.*, April, 1922.)—Observations were made with crystals of quartz, tourmaline and mica, having approximate thicknesses of 5, 4 and 1 mm., respectively. Daylight was used with a red filter. In accordance with a statement made in Groth's Optical Properties of Crystals it was found that the focal length of the objectives used determines the number of fringes seen in convergent polarized light. In the case of quartz with an objective of focal length 32 mm. no fringes at all were observed; two made their appearance with an objective of 22 mm. Corresponding numbers are 4, 16 mm.; 8, 8 mm.; and 11, 4 mm. Similar results hold for the two other crystals. The mathematical relation which appears to govern is this: "The rate of decrease of the number of fringes with focal length is proportional to the reciprocal of the focal length itself."　　　G. F. S.

Electrolytic Preparation of Lead Arsenate.—HERMAN V. TARTAR and GARY G. GRANT, of the University of Washington (*Jour. Ind. Eng. Chem.*, 1922, xiv, 311–313), have devised a method for the preparation of lead arsenates by means of the electric current. Lead electrodes are used. When the bath contains disodium arsenate, the product contains a large percentage of a basic lead arsenate, $Pb_5.OH.(AsO_4)_3.3H_2O$. When the bath contains arsenic acid, the product contains a large proportion of lead arsenate,

$PbHAsO_4$; this salt is widely used as an insecticide. The conditions most satisfactory for the electrolysis are: A current density between 1.25 and 1.875 amperes per square decimetre, a distance between the electrodes of from 2.5 to 5.0 centimetres, a bath containing from 1 to 2 per cent. of sodium chlorate as an electrolyte and approximately 0.05 per cent. arsenic acid. Lead arsenate forms as a precipitate during the electrolysis. If the precipitate be permitted to stand in contact with the bath solution for several days, the proportion of the salt $PbHAsO_4$ is increased. When several per cent. of arsenic acid are added to the bath, the precipitate does not form, and lead is deposited on the cathode.   J. S. H.

Measurement of the Pressure of the Sun's Atmosphere. A. PEROT. (*Comptes Rendus,* April 3, 1922.)—About a year ago Perot pointed out the possibility of measuring pressures within gaseous masses by studying the connection between the pressure and the ratio of the wave-lengths of two radiations either emitted or absorbed by the gas. These two radiations must be differently affected by pressure. This procedure is independent in its results of both the Doppler and of the Einstein effects. The application of this method by its author to that region of the sun's atmosphere where the b lines of magnesium are absorbed indicated that the pressure there is practically zero. Later Salet found pressures of some tenths of an atmosphere to obtain where the iron lines originate in the sun and in certain stars. Now Perot has used five iron lines, two of which have a high pressure coefficient and the others a low one. He obtains these values for the pressure in the sun 38, 24 and 41 cm. of mercury, agreeing well with Salet's results.

An interesting by-product of these results is that they remove some anomalies in certain comparisons made by Fabry and Buisson and thus indirectly strengthen Einstein's law.   G. F. S.

INDEX TO VOL. 193.